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UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN No. 1155

Washington, D. C. June, 1923

RICE EXPERIMENTS AT THE BIGGS RICE FIELD STATION IN CALIFORNIA

By

JENKIN W. JONES

Agronomist, Office of Cereal Investigations, Bureau of Plant Industry

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HISTORY OF RICE GROWING IN CALIFORNIA.

Until recent years the cultivation of rice on a commercial scale in the United States was confined to the South Atlantic and Gulf States. The coastal section of South Carolina and Georgia was long the principal area of commercial production, but with the freeing of the slaves the industry rapidly disappeared there. About 1885 rice production was begun on the broad prairies of southwestern Louisiana. From that time until about 10 years ago commercial rice production in the United States was confined almost entirely to Louisiana, Texas, and Arkansas.

[a] The experiments herein described were carried on in cooperation with the Sacramento Valley Grain Association.

Many years ago attempts were made to grow rice in California, but these did not prove successful. In the statistical report of the California State Board of Agriculture for 1919 these early attempts are briefly reviewed as follows:

> Half a century ago experiments were made in the cultivation of rice in California, but they were not successful. In 1860 small quantities were raised in Alameda, Tehama, San Mateo, Santa Cruz, and Sonoma Counties, but the total amount produced was only 2,140 pounds. * * * In 1862 the following premiums were offered by the legislature: For the first 1,000 pounds of rice, $250; for the first 5,000 pounds, $500; for the first 10,000 pounds, $1,000; and the same sums for the first, second, and third succeeding years.[1]

These financial inducements failed to stimulate the growth of the rice industry in California at that time, though it has been developed during recent years. In 1906 Japanese rice was grown and matured in Fresno County, Calif. In 1907 Prof. W. W. Mackie, then of the Bureau of Soils of the United States Department of Agriculture, in cooperation with O. H. Miller, of the Sacramento Valley Development Association, sowed Japanese rice on the farm of Mr. Gates at Elk Grove, in Sacramento County, and at Stockton in cooperation with the State Insane Asylum, but both plats failed to mature. In January, 1908, Prof. W. W. Mackie met the Biggs Chamber of Commerce. With H. S. Brink, a member of that organization, he inspected the adobe lands west of Biggs and reported that they were suitable for rice culture. Later, in cooperation with the Biggs Chamber of Commerce, the Sutter-Butte Canal Co., and the Southern Pacific Railroad Co., several acres of Japanese and of Honduras rice were sown on the Crane ranch, southwest of Biggs. The Japanese rice might have matured had it been properly irrigated, but conditions were unsuitable for the Honduras rice and it failed to mature. The rice was harvested by George Harvey and J. Crane, of Biggs.

In July, 1908, Dr. B. T. Galloway, Chief of the Bureau of Plant Industry, sent Charles E. Chambliss of the Office of Cereal Investigations to California on a reconnaissance trip to arrange for experiments in suitable localities to determine the possibilities of commercial rice production in that State. With H. L. Blanchard, then in charge of cereal investigations for the Bureau of Plant Industry at Ceres, Calif., and Prof. W. W. Mackie, Mr. Chambliss inspected the rice growing at Biggs. He discussed the possibility of rice production with ranchers in the Sacramento and San Joaquin Valleys and arranged for preliminary experiments, which were conducted under his supervision by the Office of Cereal Investigations the following year on the ranch of William Grant, about 9 miles west of Biggs. About 300 varieties and selections were grown, each occupying four rows 1 rod long. On the basis of their performance under these conditions, 26 varieties were chosen for growing in 1910 on tenth-acre plats on the Grant ranch,[2] where experiments were also continued in 1911. Ranchers in the Sacramento and San Joaquin Valleys cooperated with the Office of Cereal Investigations in growing rice on a small scale in 1910, 1911, and 1912. In 1911 arrangements were made through O. H. Miller of the Sacramento Valley Development Association for varietal experiments near Willows, Calif.,

[1] Rice. *In* Statis. Rpt. Calif. State Bd. Agr. 1919, p. 84. 1920.

[2] Chambliss, Charles E. A preliminary report on rice growing in the Sacramento Valley. U. S. Dept. Agr., Bur. Plant Indus. Circ. 97, 10 p., 4 pl. 1912.

this being the first rice to be grown west of the Sacramento River. In 1912 and 1913 experiments were conducted on the Moulton ranch near Colusa.

The investigations conducted by the Department of Agriculture during the 3-year period, 1909 to 1911, inclusive, gave some valuable data on the commercial possibilities of rice culture in California and were largely responsible for the beginning of the commercial industry. The acreage, acre yield, production, and farm value on December 1 of rice produced in California from 1912 to 1922, inclusive, are shown in Table 1. These figures show the rapid increase of rice production in the State.

TABLE 1.—*Acreage, acre yield, production, and farm value of rice in California from 1912 to 1922, inclusive.*

Year.	Acreage.	Production (bushels).		Farm value Dec. 1.	Year.	Acreage.	Production (bushels).		Farm value Dec. 1.
		Per acre.	Total.				Per acre.	Total.	
1912	1,400	50.0	70,000	$64,000	1918	106,220	66.0	7,011,000	$13,321,000
1913	6,100	48.0	293,000	293,000	1919	142,000	55.5	7,881,000	21,042,000
1914	15,000	53.3	800,000	800,000	1920	162,000	60.0	9,720,000	11,761,000
1915	34,000	66.7	2,268,000	2,041,000	1921	135,000	54.0	7,290,000	8,384,000
1916	55,300	59.0	3,263,000	2,545,000	1922 (esti-				
1917	80,000	70.0	5,600,000	9,800,000	mated)..	140,000	59.0	8,260,000	9,086,000

THE BIGGS RICE FIELD STATION.[3]

By 1912 interest in rice growing in California had increased to a point where commercial sowings of 1,400 acres were made near Biggs. The interest of the rice farmers and others was awakened in the establishment of a rice experiment station. As a result, a group of business men and farmers formed the Sacramento Valley Grain Association to cooperate with the United States Department of Agriculture in establishing such a station. The association agreed to provide a tract of land and equip it with the necessary buildings. The Department of Agriculture agreed to furnish the scientific personnel and the ordinary running expenses so far as possible and to conduct experiments in rice improvement and production. The land selected was a tract of 57 acres, located 4½ miles northwest of Biggs and thereafter designated as the Biggs Rice Field Station. The station was located and equipped in 1912 and the first crop sown in 1913. In 1916, 12½ acres of additional land were leased for experimental use. The buildings at the Biggs Rice Field Station are shown in Figure 1.

ENVIRONMENTAL CONDITIONS.

SOIL.

The soil on the Biggs Rice Field Station is Stockton clay adobe, a dark-gray to black clay which is very sticky and waxy when wet and filled with cracks and checks when dry. The humus content as indi-

[3] The Biggs Rice Field Station has been operated under the general supervision of Charles E. Chambliss, agronomist in charge of rice investigations, Office of Cereal Investigations. The experiments were conducted by Ernest L. Adams, assistant agronomist, from the establishment of the station in 1912 till April 1, 1918, and since the latter date by the writer.

cated by color is quite high. It is probably the most pronounced adobe soil in the Sacramento Valley and but for its adobe structure would be almost impossible to till. The dark-colored surface soil grades into lighter colored buff, light-brown, brownish yellow, or yellowish clays at depths varying from 18 to 36 inches.

The subsoil is distinctly calcareous and between the soil and subsoil there is usually a well-defined impervious calcareous hardpan. The soil holds water well, but cracks and checks badly when thoroughly dry and is very difficult to work when either too wet or too dry. When plowed wet and exposed to rain and sunshine, this soil breaks down into a mass of pea-sized particles.

The principal soils on which rice is grown in the Sacramento Valley are the clays and clay adobes of the Stockton, Willows, Sacramento, Capay, and Yolo series. The soil at the station is representative of a large part of the area on which rice is grown in California. The

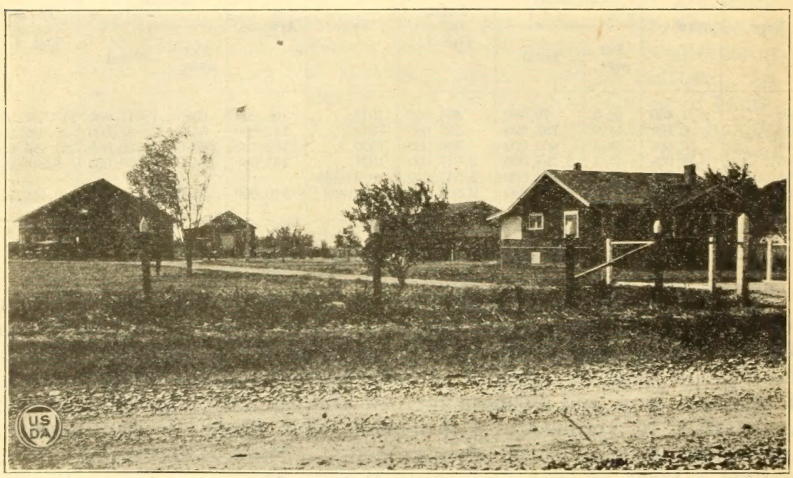

FIG. 1.—Buildings at the Biggs Rice Field Station, Biggs, Calif.

results obtained at the Biggs Rice Field Station are applicable in a general way to other sections of the Sacramento Valley in which rice is grown. However, on the lighter soils and in sections where alkali is much in evidence, a slightly different method of irrigation may be necessary to secure the best results.[4]

TEMPERATURE.

The Sacramento Valley is subject to wide ranges of temperature. The winters are comparatively cool, but temperatures below 20° F. are seldom recorded, and freezing weather is infrequent. The springs are warm and the summers are hot, though the summer nights are usually comparatively cool. The fall is usually warm but seldom hot.

Table 2 presents data showing the maximum, minimum, and greatest range in temperature from April 1 to October 31 in the 9-year period from 1913 to 1921, inclusive.

[4] Adams, Frank. Rice irrigation measurements and experiments in Sacramento Valley, 1914–1919. Calif. Agr. Exp. Sta. Bul. 325, p. 45–69, 4 fig. 1920.

TABLE 2.—*Maximum, minimum, and greatest range in temperature at the Biggs Rice Field Station, Biggs, Calif., from April 1 to October 31 for each year during the 9-year period from 1913 to 1921, inclusive.*

[Data in degrees F.]

Year.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
Maximum:							
1913	86	100	99	108	112	110	97
1914	84	100	107	110	107	99	93
1915	86	96	102	107	105	98	92
1916	84	87	102	105	104	96	81
1917	85	86	107	111	103	101	100
1918	87	88	110	103	105	90	89
1919	86	99	102	108	103	97	90
1920	91	95	107	104	106	99	86
1921	89	92	107	107	104	99	91
Minimum:							
1913	31	40	47	53	53	47	38
1914	39	46	47	55	49	47	38
1915	40	40	54	55	56	47	40
1916	37	36	46	50	50	49	35
1917	28	39	47	56	55	45	37
1918	32	43	52	52	54	52	35
1919	36	43	50	51	52	47	33
1920	34	40	52	54	55	43	34
1921	28	31	50	53	53	49	37
Greatest range:							
1913	40	46	48	50	46	48	52
1914	33	39	43	47	49	44	46
1915	37	34	41	40	44	40	45
1916	37	37	44	45	42	42	37
1917	39	39	43	44	43	43	46
1918	44	44	45	44	38	36	41
1919	36	41	46	43	41	42	47
1920	46	43	44	44	40	39	40
1921	45	39	41	43	41	43	42

June, July, and August are the hottest months, with maximum temperatures of 99° F. or higher each year. April and October are the coolest months for which data are recorded in the table. The lowest temperature recorded in April was 28° F. in 1917 and 1921, while the lowest temperature recorded in October was 33° in 1919.

The greatest daily range in temperature in the 9-year period was 52° F. in October, 1913. A daily range of 40° in temperature is quite common. These wide fluctuations in temperature between day and night affect the development of the rice crop, and only the hardier types of rice do well under such conditions.

RAINFALL.

Table 3 presents data showing the monthly, average monthly, yearly, and average yearly precipitation for the 9-year period from 1913 to 1921, inclusive, at the Biggs Rice Field Station.

TABLE 3.—*Monthly, average monthly, annual, and average annual precipitation at the Biggs Rice Field Station, Biggs, Calif., for the 9-year period from 1913 to 1921, inclusive.*

[Data in inches; T=trace.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1913	3.51	0.79	1.11	3.16	1.39	0	0	0	0	0.20	6.67	8.28	25.11
1914	10.83	5.36	.54	1.59	.50	1.81	0	0	0	.89	.33	4.40	26.25
1915	7.60	9.04	2.03	.75	3.57	0	0	0	0	0	1.11	6.89	30.99
1916	10.24	3.43	.94	0	.25	.29	.37	0	.66	1.67	1.34	4.82	24.01
1917	2.44	4.75	1.28	1.41	.66	0	0	0	.55	0	1.58	1.26	13.93
1918	.78	4.22	5.36	0	.35	0	0	0	3.00	.66	2.61	1.71	18.69
1919	2.87	5.21	1.76	.08	.14	0	0	0	.98	.29	.64	2.73	14.70
1920	.31	1.93	3.67	.96	0	.14	.03	0	T	1.81	7.67	7.37	23.89
1921	4.74	1.48	1.83	.35	.74	.11	0	0	0	.91	2.19	5.14	17.49
Average	4.81	4.02	2.06	.92	.84	.26	.04	0	.58	.73	2.68	4.73	21.67

In 1913, 1914, and 1915 the precipitation was above normal (normal for a 49-year period is 23.01 inches); in 1917, 1918, 1919, and 1921 the precipitation was far below normal, while in 1916 and 1920 it was slightly above normal. The average precipitation for the 9-year period from 1913 to 1921 was 21.67 inches. The months of greatest precipitation are December, January, and February. Little or no rain falls during June, July, and August. The average monthly precipitation in inches at the Biggs Rice Field Station from 1913 to 1921, inclusive, is shown graphically in Figure 2.

Heavy continuous rains in October and November may result in serious losses to rice growers in the valley. In the fall of 1920 only about half of the rice crop was warehoused when the heavy rains began on November 7. The remainder of the crop stayed in the

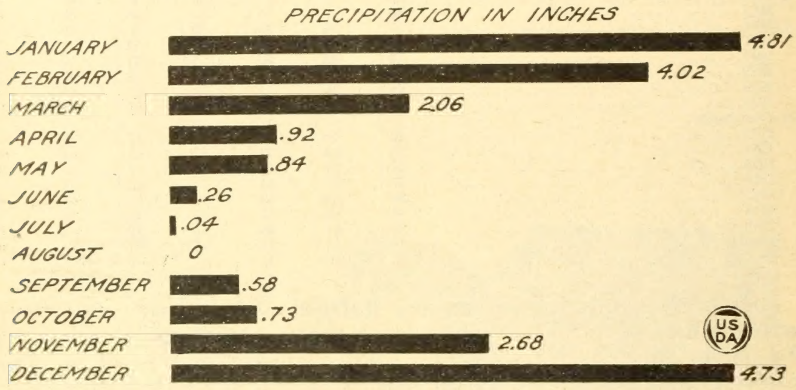

FIG. 2.—Average monthly precipitation (in inches) at the Biggs Rice Field Station during the 9-year period from 1913 to 1921, inclusive.

fields until spring, much of it was lost, and that which was salvaged was badly damaged.

WIND.

Table 4 presents data showing the maximum, minimum, and average monthly wind velocity in miles per hour from April to October, inclusive, during the 9-year period from 1913 to 1921, inclusive.

The maximum velocity recorded for any month during this period was 16.1 miles per hour and the minimum 0.1 mile per hour. The average daily velocity ranged from 1.6 miles per hour, in October, 1921, to 5.3 miles, in May, 1915.

In general, this section has but little wind, though strong winds sometimes blow from the north. These, if very brisk, are known as "northers," and are welcome at harvest time because of their effective drying qualities. A strong north wind for 24 hours is equal to about a week of sunshine for drying purposes.

TABLE 4.—*Maximum, minimum, and average monthly wind velocity at the Biggs Rice Field Station, Biggs, Calif., from April 1 to October 31, for each year during the 9-year period from 1913 to 1921, inclusive.*

[Data in miles per hour.]

Year.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
Maximum:							
1913				14.0	9.6	13.7	12.6
1914	7.1	11.0	12.0	7.5	7.1	13.2	8.7
1915	12.1	12.8	11.7	7.2	3.5	6.7	8.2
1916	12.4	11.3	9.7	8.1	8.7	6.9	9.7
1917	10.6	8.6	9.4	5.9	4.0	9.0	7.9
1918	15.7	8.5	5.8	9.5	5.9	4.9	5.3
1919	8.4	12.1	7.4	6.0	5.8	6.8	6.9
1920	16.1	8.7	8.7	7.9	5.8	5.6	5.7
1921	10.7	9.6	8.5	13.7	5.9	6.8	6.0
Minimum:							
1913				1.1	.8	.6	.3
1914	.6	.4	.1	.4	1.0	1.5	.3
1915	1.4	1.8	.1	1.3	1.0	.6	.9
1916	.5	1.2	1.4	1.7	1.4	.9	.2
1917	1.3	1.8	.2	.2	.9	1.1	.6
1918	1.3	2.0	.6	.7	.4	.2	.1
1919	.7	.6	.8	1.1	.9	.4	.3
1920	.9	.9	.4	1.0	.5	.2	.1
1921	.9	1.0	.6	1.0	.8	.7	.3
Average:							
1913				5.1	4.2	3.9	4.1
1914	3.5	3.8	5.2	4.2	3.2	4.9	3.5
1915	4.9	5.3	4.3	3.2	2.1	2.2	2.3
1916	4.5	5.0	4.2	3.6	3.2	3.0	2.2
1917	5.2	4.5	4.1	2.4	2.3	4.0	2.7
1918	4.4	3.9	2.2	3.1	2.3	1.7	1.7
1919	3.2	2.9	3.9	3.2	2.5	2.8	3.2
1920	4.2	3.2	4.3	3.2	1.7	2.0	2.0
1921	3.9	3.6	3.4	3.0	2.4	2.4	1.6

EVAPORATION.

Table 5 gives data on the maximum, minimum, and average daily evaporation in inches from April to October, inclusive, by months, during the 9-year period from 1913 to 1921, inclusive.

TABLE 5.—*Maximum, minimum, and average daily evaporation at the Biggs Rice Field Station, Biggs, Calif., from April to October during the 9-year period from 1913 to 1921, inclusive.*

[Data in inches.]

Year.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.
Maximum:							
1913			0.537	0.749	0.476	0.762	0.511
1914	0.287	0.339	.475	.427	.365	.308	.416
1915	.318	.320	.493	.483	.426	.381	.340
1916		.432	.480	.510	.495	.548	.232
1917	.270	.392	.576	.485	.420	.315	
1918		.575	.687	.469	.416	.242	.246
1919			.430	.445	.378	.316	.205
1920	.266	.367	.357	.472	.380	.255	.184
1921	.362	.446	.402	.513	.395	.282	.163
Minimum:							
1913			.127	.102	.183	.051	.006
1914	.036	.050	.111	.013	.131	.127	.032
1915	.044	.060	.127	.174	.122	.096	.081
1916		.010	.167	.116	.129	.094	.045
1917	.074	.081	.196	.219	.166	.061	
1918		.031	.155	.170	.062	.026	.016
1919			.154	.183	.153	.047	.022
1920	.072	.114	.069	.097	.025	.062	.036
1921	.056	.065	.009	.152	.175	.097	.037
Average:							
1913			.304	.361	.298	.258	.200
1914	.128	.186	.242	.266	.218	.192	.097
1915	.113	.161	.283	.310	.252	.197	.144
1916		.231	.309	.299	.263	.209	.088
1917	.136	.197	.315	.326	.264	.205	
1918		.410	.407	.281	.227	.132	.145
1919			.300	.313	.253	.183	.137
1920	.145	.214	.239	.229	.201	.156	.090
1921	.181	.189	.235	.293	.253	.165	.093

The highest daily evaporation was 0.762 inch, in September, 1913, and the lowest daily evaporation was 0.006 inch, in October, 1913. The average daily evaporation ranged from 0.088 inch, in October, 1916, to 0.410 inch, in May, 1918.

Table 6 presents data on the monthly, average monthly, seasonal, and average seasonal evaporation from April to October, inclusive, for the 9-year period from 1913 to 1921, inclusive.

TABLE 6.—*Monthly, average monthly, seasonal, and average seasonal evaporation at the Biggs Rice Field Station, Biggs, Calif., from April to October during the 9-year period from 1913 to 1921, inclusive.*

[Data in inches.]

Month.	1913	1914	1915	1916	1917	1918	1919	1920	1921	Average.
April	.....	3.840	3.383	.....	4.091	.....	.....	4.363	5.243	.....
May	.....	5.789	4.996	7.161	6.119	[1] 6.970	.....	[2] 3.845	5.853	.....
June	9.120	7.348	8.500	9.261	9.448	12.224	8.991	7.160	7.052	8.789
July	11.216	8.263	9.618	9.270	10.110	8.679	9.692	7.104	9.076	9.225
August	9.247	6.775	7.825	8.152	8.178	7.035	7.858	6.227	7.845	7.682
September	8.767	5.760	5.912	6.279	6.158	3.946	5.497	4.691	4.956	5.774
October	6.221	3.003	4.466	2.713	.....	4.480	4.256	2.793	2.879	.....
Total:										
June to October	44.571	31.149	36.321	35.675	.....	36.364	36.294	27.975	31.808	35.020
May to October	.....	36.938	41.317	42.836	.....	.....	.....	.....	37.661	39.688
April to October	.....	40.778	44.700	.....	.....	.....	.....	.....	42.904	42.794

[1] Last 17 days of May. [2] Last 18 days of May.

The highest monthly evaporation recorded during the 9-year period was 12.224 inches, in June, 1918; the lowest, 2.713 inches, in October, 1916. June, July, and August are the months of highest evaporation. The average evaporation for these three months for the 9-year period from 1913 to 1921, inclusive, was 25.696 inches. The average evaporation from April to October, inclusive, for the years 1914, 1915, and 1921 was 42.794 inches; the average evaporation from May to October, inclusive, for the years 1914, 1915, 1916,

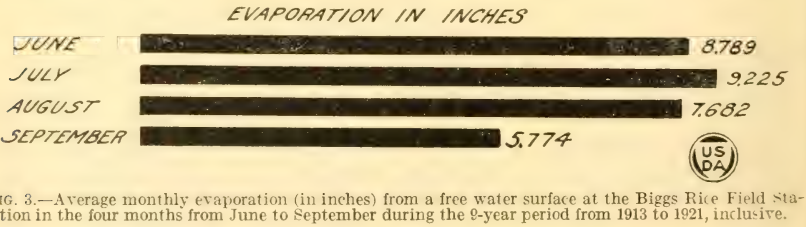

FIG. 3.—Average monthly evaporation (in inches) from a free water surface at the Biggs Rice Field Station in the four months from June to September during the 9-year period from 1913 to 1921, inclusive.

and 1921 was 39.688 inches; and the average evaporation from June to October, inclusive, for the 9-year period from 1913 to 1921, with 1917 omitted, was 35.020 inches. The average monthly evaporation in inches at the Biggs Rice Field Station from June to September, inclusive, in the 9-year period from 1913 to 1921, is shown graphically in Figure 3.

Water measurements show that it requires about 5 acre-feet, or 60 inches, of water to produce a crop of rice on Stockton clay adobe soil. The evaporation records show that at least 40 inches of water evaporates from a free water surface during the rice-growing season. Assuming that the shading of the water by the rice during the sub-

mergence period (June to September) reduces evaporation 25 per cent, there is a loss by evaporation of 30 inches, or half of the irrigation water applied to the rice crop.

CULTURAL EXPERIMENTS.

The cultural experiments which have been conducted include studies of different depths, dates, and rates of seeding and different methods of preparing the seed bed for rice. The experiments in 1913 and 1914 were conducted on land which had not previously been cropped to rice. In 1915 and 1916 they were on land on which one crop of rice had been grown previously, but which was fallowed during the year immediately preceding. The experiments in 1917 and 1918 were on fallowed land that had grown two crops of rice, in 1919 and 1920 on fallowed land that had grown three crops of rice, and in 1921 on fallowed land that had grown four rice crops.

The usual method of preparation was to plow the land in June for fallow, following an irrigation late in May. The fallow is left rough and is given no further treatment until the following spring, when it is disked or shallow plowed. If the land is dry enough in late February or early March it may be double-disked at that time and again just before seeding. One of the principal objects of the thorough disking is to kill weeds, which usually make a heavy growth on the land in late winter and early spring. If the stand of weeds and weedy grasses is thick, it is often better to plow the land shallow than to attempt to destroy them by disking. In these experiments the plats have usually been spring plowed. After plowing or disking, a good seed bed is prepared by harrowing and dragging.

In the various experiments, all plats have been prepared alike each year except for the particular factor under investigation. Thus, in the date-of-seeding experiment, the preparation of the land, method of seeding, rate of seeding, and all other factors have been uniform except that the different plats have been sown on varying dates.

DEPTH OF SEEDING.

The yields obtained in depth-of-seeding experiments during the 9-year period from 1913 to 1921, inclusive, are shown in Table 7. These yields are the average yields of two tenth-acre plats each year for each depth of seeding. The 1920 yields are omitted because of damage to the crop by rains before it could be threshed. The preparation of the land and the rate, time, and manner of seeding were the same for all plats, but the depth of seeding on the various plats was 1, 2, and 3 inches, respectively.

TABLE 7.—*Annual and average yields of Wataribune rice obtained in the depth-of-seeding experiments at the Biggs Rice Field Station, Biggs, Calif., during the 9-year period from 1913 to 1921, inclusive.*

Depth of seeding.	Yield per acre (pounds).[1]								
	1913	1914	1915	1916	1917	1918	1919	1921	Average
1 inch	6,305	5,170	5,290	3,805	4,975	2,790	2,755	3,140	4,279
2 inches	6,360	5,588	5,440	3,695	4,890	2,915	3,125	3,375	4,423
3 inches	6,050	5,240	4,180	3,575	4,490	3,125	2,365	3,205	4,029

[1] The 1920 yields are omitted because of damage to the crop by rains, floods, birds, and field mice before it could be threshed in the spring of 1921.

In five of the years the 2-inch depth of seeding produced the highest yields; in two, the plats sown at the 1-inch depth, and in one, those sown at the 3-inch depth yielded best. The highest average yield, 4,423 pounds per acre, was obtained from the plats seeded 2 inches deep. The plats seeded 1 inch deep ranked second, with an average yield of 4,279 pounds per acre. The average yields in the depth-of-seeding experiments with rice at the Biggs Field Station from 1913 to 1921, inclusive (1920 omitted), are shown graphically in Figure 4.

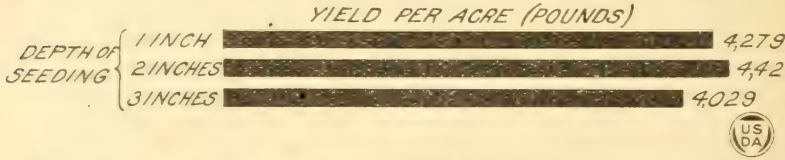

FIG. 4.—Average acre yields of Wataribune rice obtained in the depth-of-seeding experiments at the Biggs Rice Field Station during the 9-year period from 1913 to 1921 (1920 omitted).

On an exceptionally good or a rough cloddy seed bed the best stands are usually obtained from shallow seeding. On heavy soil, such as the Stockton clay adobe, if the seed bed is finely pulverized and the rice is sown too deep, the flooding to start germination will run the soil together. This makes it very compact, keeps it cold, and results in the rotting of considerable seed. Again, if such a soil is cloddy and rough and the seed is sown deep, the flooding to start germination will slack the clods and bury the rice so deep that the plants are unable to emerge. Therefore, our experiments, observations, and experience all strongly indicate that on heavy soil shallow seeding, 1 to 1½ inches, is preferable to deeper seeding. On soils of lighter texture deeper seeding may be advisable. Some rice growers broadcast the rice on plowed or disked land and depend upon the first flooding of the field to bury the seeds. Although good yields have been obtained in this way, this method of seeding should not be practiced when the crop is not to be submerged continuously after seeding.

RATE OF SEEDING.

Rate-of-seeding experiments were begun in 1913, when plats were sown to Wataribune rice at rates of 60, 80, and 100 pounds to the acre. After the land had been in rice for several years it became necessary to increase these rates in order to have the stands thick enough on all plats to aid in keeping down weeds. Beginning in 1918, rates of 110, 130, and 150 pounds were used. In 1921 new rate-of-seeding experiments were begun, with three varieties and six rates of seeding for each variety.

EXPERIMENTS FROM 1913 TO 1921.

The yields from duplicate tenth-acre plats in the rate-of-seeding experiments during the 9-year period from 1913 to 1921 are shown in Table 8. The preparation of the land and the time, depth, and manner of seeding were the same on all plats. As stated above, the rates used from 1913 to 1917, inclusive, were 60, 80, and 100 pounds per acre; from 1918 to 1921, they were 110, 130, and 150 pounds. A set of plats was drilled and one sown broadcast at these rates each year.

The seed bed each year was good. Fallow ground slaked by rain and sunshine can with little effort be reduced to a perfect seed bed. The stands obtained each year were good, except those on the broadcast plats in 1913. On the drilled plats the highest yield was obtained from the heaviest rate of seeding in five of the eight years. In one of the eight years the highest yield was obtained from the medium rate of seeding and in two from the lowest rate of seeding.

TABLE 8.—*Annual and average yields obtained in the rate-of-seeding experiments with Wataribune rice at the Biggs Rice Field Station, Biggs, Calif., during the 9-year period from 1913 to 1921, inclusive.*[1]

Rate of seeding.	Yield per acre (pounds).						Rate of seeding.	Yield per acre (pounds).			
	1913	1914	1915	1916	1917	Average.		1918	1919	1921	Average.
Seed drilled:							Seed drilled:				
60 pounds	6,000	5,345	4,605	3,450	4,385	4,757	110 pounds	2,940	3,675	3,405	3,340
80 pounds	6,360	5,840	5,440	4,211	4,950	5,360	130 pounds	2,915	3,430	3,375	3,240
100 pounds	6,380	5,805	6,180	4,365	5,420	5,630	150 pounds	2,875	3,950	3,350	3,392
Seed sown broadcast:							Seed sown broadcast:				
60 pounds	[2]4,225	5,670	4,155	3,550	4,100	4,340	110 pounds	3,680	2,905	3,235	3,273
80 pounds	[2]4,955	6,125	4,435	3,895	4,195	4,821	130 pounds	3,215	2,640	3,195	3,017
100 pounds	[2]4,800	6,080	5,165	4,450	5,065	5,112	150 pounds	3,525	3,450	2,970	3,315

[1] The 1920 yields are omitted because of damage before threshing. [2] Poor stands.

The highest average yields were obtained from the heaviest rates of seeding, 5,630 pounds from the 100-pound rate in the first period, 1913 to 1917, and 3,392 pounds from the 150-pound rate in the second period, 1918 to 1921. The average yields from the medium rates of seeding in these two periods were 5,360 pounds and 3,240 pounds per acre, respectively, and those from the lowest rates were 4,757 pounds and 3,340 pounds per acre.

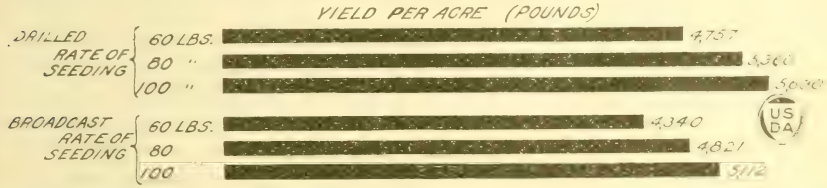

FIG. 5.—Average acre yields of Wataribune rice obtained in the rate-of-seeding experiments at the Biggs Rice Field Station during the 5-year period from 1913 to 1917, inclusive.

On the drilled plats there was a marked increase in yield during the first period with each increase in rate of seeding up to 100 pounds per acre, but from the 110, 130, and 150 pound rates in the second period there was but little difference in the average yields per acre. The average yields in the rate-of-seeding experiments with rice drilled and broadcasted at the Biggs Rice Field Station from 1913 to 1917, inclusive, are shown graphically in Figure 5.

On the broadcast and harrowed plats the highest yield was obtained from the heaviest rate of seeding in four of the eight years. In two of the eight years the highest yield was obtained from the medium rate of seeding and in two years from the lightest rate

On the broadcast plats the highest average yields, 5,112 pounds per acre in the period from 1913 to 1917 and 3,315 pounds in the period from 1918 to 1921, were obtained from the heaviest rate of seeding. The average yields from the medium rates of seeding in these two periods were 4,821 pounds and 3,017 pounds per acre, and the average yields from the lowest rates were 4,340 and 3,273 pounds per acre in the two periods.

On the broadcast plats there was a marked increase in yield during the first period from increased rates of seeding up to 100 pounds per acre, but from the 110, 130, and 150 pound rates there was but little difference in the average yields per acre.

In comparing the average yields obtained from the drilled and broadcast plats, there was a marked increase in favor of drilling during the earlier period for each rate up to 100 pounds per acre, but during the second period there appeared to be no advantage in drilling over broadcasting on a well-prepared seed bed. The rate-of-seeding experiment has been conducted on new or fallow land, on which a good seed bed has been prepared each year.

EXPERIMENTS IN 1921.

The yields obtained in rate-of-seeding experiments with three varieties of rice in 1921 are shown in Table 9. The preparation of the land, date, depth, and manner of seeding were the same on all plats, but the rate of seeding varied from 85 to 175 pounds per acre. The lowest yield of each variety was obtained from the 85-pound rate of seeding. The yields of Selection No. 175 increased with each increase in the rate of seeding up to 150 pounds per acre, but the 175-pound rate of seeding produced a lower yield than the 100, 115, or 130 pound rates. The yields of Caloro varied, but did not give consistent increases with the increased rates of seeding, though the highest yield was obtained from the 175-pound rate. The yields of Wataribune show a gradual increase, except for the 130-pound rate, with each increasing rate up to 150 pounds per acre.

TABLE 9. — *Yields obtained from three varieties of rice in the rate-of-seeding experiments at the Biggs Rice Field Station, Biggs, Calif., in 1921.*

Rate of seeding.	Yield per acre (pounds).[1]			
	Selection No. 175.	Caloro.	Wataribune (C. I. 1561).	Average.
85 pounds	1,880	2,380	2,150	2,137
100 pounds	2,660	2,630	2,800	2,697
115 pounds	2,710	2,460	3,210	2,793
130 pounds	2,740	2,510	3,160	2,803
150 pounds	3,030	2,860	3,640	3,177
175 pounds	2,450	3,080	3,290	2,940
Average	2,578	2,653	3,042	

[1] Yields from single tenth-acre plats.

The average yields of the three varieties at each rate show increases in yields with each increase in the rate of seeding up to 150 pounds per acre. The average yield of the three varieties sown at

the rate of 175 pounds per acre was less than the average yield from the 150-pound rate, but higher than that from any of the other rates. The 1921 yields indicate that 150 pounds per acre is probably the best rate of seeding on old land. These yields were obtained on an ideal seed bed, much better than the usual seed beds on commercial fields. Therefore, on commercial seed beds the higher rates of seeding could be expected to give even greater differences in yield. Thin stands result in excessive tillering, uneven ripening, and usually a poor quality of rice.

FACTORS INFLUENCING THE RATE OF SEEDING.

Many factors must be taken into consideration in determining the best rate of seeding. Among these are previous cropping, character of seed bed, kind of land, time of seeding, seed, variety, manner of seeding, drainage, and method of irrigation.

More seed is required to obtain a good stand on land on which several crops of rice have been grown than on new land. Rice on old land does not stool as well as on new land. Therefore, it is necessary to increase the rate of seeding as the land becomes old.

More seed is required to obtain good stands on a rough seed bed than on a good one. More seed also is required on heavy, cold land than on lighter, warmer soil.

If rice is seeded early in the spring, when the soil, water, and air are all cold, more seed is required than for seeding later, when conditions are more favorable for germination.

A smaller quantity of well-matured, recleaned seed than of inferior seed is required to secure good stands.

All varieties should not be seeded at the same rate, because some stool much more freely than others. Wataribune rice stools much more than Colusa (C. I. No. 1600) under the same conditions. Wataribune does not stool as much on old land as it does on new or second-year land. All varieties stool more heavily on rich land than on poor land.

Less seed is required where rice is drilled than when sown broadcast. On poorly drained, cold land more seed is required to secure good stands than on other soils, because conditions are usually unfavorable for germination on poorly drained soils.

If the best methods of irrigation are not practiced or if water for the initial flooding is not plentiful and therefore a long time is taken to cover the field, more seed per acre is required, because some of the seed is likely to rot before the field is covered and the water removed.

Because of all these factors it is not possible to say what rate of seeding is best under all conditions. Many factors should be considered, and usually all favorable factors are not present in any one place at the same time.

Early varieties on new land should be sown at about 100 to 110 pounds per acre, and late varieties at 90 to 100 pounds. Early varieties on second-year land should be sown at 110 to 120 pounds per acre, and late ones at 100 to 110 pounds per acre. On third and fourth year land the rates should be increased in each case from 5 to 15 pounds per acre.

DATE OF SEEDING.

The yields obtained in date-of-seeding experiments on duplicate tenth-acre plats during the 9-year period from 1913 to 1921, inclusive, are presented in Table 10. The preparation of the land and the rate, depth, and manner of seeding were the same for all plats, but the dates of seeding varied. The first seeding was made as early in the spring as possible, the date ranging from March 15 to April 23; the second seeding was two weeks later; the third seeding was two weeks after the second; and the fourth seeding two weeks after the third. These dates of seeding ranged from March 15 to June 1. Because of weather conditions it was not possible to sow at the same time each year.

TABLE 10.—*Annual and average yields obtained in the date-of-seeding experiments with Wataribune rice at the Biggs Rice Field Station, Biggs, Calif., for the 9-year period from 1913 to 1921, inclusive.*

Date of seeding.	Yield per acre (pounds).[1]									Average.	
	1913	1914	1915	1916	1917	1918	1919	1920	1921	1913 to 1917.	1913 to 1921.
First	6,380	5,805	5,440	4,283	4,890	3,130	3,430	2,130	3,095	5,360	4,287
Second	5,955	5,845	4,985	4,100	4,845	2,760	2,700	1,920	1,965	5,146	3,897
Third	5,545	5,400	4,350	3,850	4,540	2,955	1,965	1,250	780	4,737	3,404
Fourth	4,885	5,045	3,410	3,450	4,110	.....	.....	.....	.....	4,180	.....

[1] Average yields from duplicated tenth-acre plats each year, with the exception of the third and fourth dates in 1917.

In every year except 1914 the highest yield was obtained from the earliest date of seeding. With one exception, 1918, there was a marked decrease in yield from each successive date of seeding.

Rice sown late in the spring, when the temperatures are higher and the water warmer than in early spring, germinates quicker, grows faster, stools less, and matures at nearly the same time as rice sown a month earlier, but the yield is less and the quality poorer than that from rice sown early.

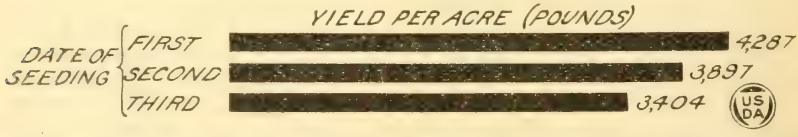

FIG. 6.—Average acre yields of Wataribune rice obtained in the date-of-seeding experiments at the Biggs Rice Field Station during the 9-year period from 1913 to 1921, inclusive.

The highest average yield, 4,287 pounds per acre, was obtained from the earliest seeding date. The plats seeded 15 days later gave an average yield of 3,897 pounds per acre, and the third date of seeding gave an average yield of 3,404 pounds per acre. The average yields in the date-of-seeding experiments at the Biggs Rice Field Station from 1913 to 1921, inclusive, are shown graphically in Figure 6.

The Wataribune variety was used in this experiment. Wataribune is a late-maturing variety, not well suited for late sowing in this section. An early variety, such as Colusa or Onsen, can be seeded

safely later and will produce rice of good quality. Late seeding of either early or late varieties, however, is not good practice, as the possibilities of loss in the fall from heavy rains are too great to be ignored. The evidence available indicates that rice should be sown as early as the land and weather permit, provided water for flooding is available.

PREPARATION OF THE SEED BED.

Table 11 shows the yields obtained from duplicate tenth-acre plats in experiments in which a smooth seed bed was compared with plats disked but left rough during the 9-year period from 1913 to 1921, inclusive. Since 1915 the experiment has been conducted on land fallowed the previous year, and there has not been a wide difference between the two plats. Fallow land pulverizes readily the following spring, and even when not replowed the desired roughness has not always been present. However, the smooth plats have been in better condition than the rough plats at seeding time. The average yields for the 9-year period show a slight increase for the smooth over the rough seed bed.

TABLE 11.—*Annual and average yields in the seed-bed preparation experiments with Wataribune rice at the Biggs Rice Field Station, Biggs, Calif., for the 9-year period from 1913 to 1921, inclusive.*

Treatment.	Yield per acre (pounds).[1]									
	1913	1914	1915	1916	1917	1918	1919	1920	1921	Average.
Disked, surface rough	6,160	5,765	4,660	3,760	4,680	3,395	2,570	2,640	2,650	4,031
Disked, surface smooth	6,255	6,135	5,020	4,415	4,895	3,590	2,475	2,920	2,865	4,280

[1] Average yields from duplicated tenth-acre plats each year.

CONTINUOUS CROPPING TO RICE.

In California three or four crops of rice are all that have been profitably grown in succession on the same land. This is due primarily to the fact that weeds increase so rapidly that it is not possible to grow profitable crops on foul land and not because the rice has robbed the soil of its fertility. Analyses show that wheat and rice with equal yields remove from the soil about the same quantity of plant food per acre.

Continuous cropping to rice is hard on the land, for the same reasons that continuous cropping to any crop is detrimental. Permanent agriculture is based upon diversification and rotation of crops. Every agricultural section has its weed problems, and the solution is usually crop rotation. Maximum yields with all cereal crops are obtained in rotation systems and not by cropping continuously to the same crop year after year. The yields obtained from rice grown continuously on the same land for the 7-year period from 1913 to 1919, inclusive, were as follows: 1913, 5,677 pounds; 1914, 3,692 pounds; 1915, 3,914 pounds; 1916, 3,231 pounds; 1917, 3,690 pounds; 1918, 2,706 pounds; and 1919, 1,799 pounds. The yield in 1913 was the average from 10 tenth-acre plats; in 1914, 1915, and 1916, from 12 tenth-acre plats; and in 1917, 1918, and 1919, from 7 tenth-acre plats.

The soil on which this experiment was conducted is Stockton clay adobe. The land was fall-plowed each year except 1918, well prepared in the spring before seeding, and kept free from water grasses and tules. Plowing for the 1918 crop was not done till the spring of that year. New land usually produces about one-third more per acre than second or third year land. The yields just stated do not show a gradual decline as the land becomes old, but erratic changes, possibly due to favorable or unfavorable weather conditions in different years. The yield in 1914 was less than in 1915 and about the same as in 1917. In 1918 and 1919 the yields were much lower than in the preceding years. The average yield for the 7-year period was 3,528 pounds per acre, which is above the average yield for the State each year.

These yields show that if weeds are kept under control the land will produce rice for at least seven years in succession, though commercially it has not been possible to grow rice more than three or four years in succession, because the cost of eradicating weeds was prohibitive.

Land that is foul with water grasses and cat-tails, if spring-plowed and fallowed, will grow barley or wheat the following year, after which a crop of rice can be grown.

IRRIGATION EXPERIMENTS.[5]

The irrigation experiments at the Biggs Rice Field Station have been conducted cooperatively by the Office of Cereal Investigations of the Bureau of Plant Industry and the Office of Irrigation Investigations of the Bureau of Public Roads and Rural Engineering. When these experiments were started in the spring of 1914, the rice industry in California was still in its infancy. Information regarding the best methods of irrigation for rice was sorely needed.

The plan of the experiments included a study of the effect of varying the dates of submerging the rice crop, of varying the depth of submerging the crop, of fluctuating the depth of water during the submergence period, of slow changing versus stagnant water during submergence, and of no submergence but the ground kept wet by frequent irrigations. During the conduct of these experiments water grass had not become so much of a menace as it now is, and the experiments were therefore concerned primarily with yield under the different irrigation treatments rather than with water-grass control, which has since become one of the chief subjects of investigation.

The irrigation experiments were conducted on fifth-acre plats in 1914, 1915, 1916, 1918, and 1920. In 1917, 1919, and 1921 the experiments were on tenth-acre plats. In 1914 the irrigation experiments were on new land, in 1915 on second-year land, in 1916 on third-year land, in 1917 and 1918 on fallowed land that had produced three rice crops, in 1919 and 1920 on fallowed land that had produced four rice crops, and in 1921 on fallowed land that had produced five rice crops. Good stands were obtained each year.

[5] For further data on the irrigation of rice in California, see Adams, Frank, Rice irrigation measurements and experiments in the Sacramento Valley, 1914-1919, Calif. Agr. Exp. Sta. Bul. 325, p. 45-69, 4 fig., 1920.

TIME OF SUBMERGENCE.

Table 12 shows the yields obtained from the time-of-submergence irrigation experiments during the 8-year period from 1914 to 1921, inclusive. In six of the eight years the highest yield was obtained by submerging the land 30 days after the rice emerged. In five of the eight years higher yields were obtained by submerging the land 45 days after emergence than by submerging 15 or 60 days after the rice had emerged.

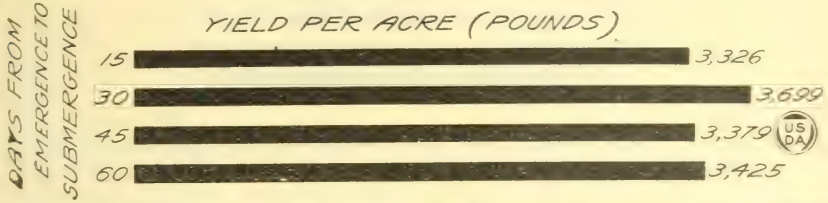

FIG. 7.—Average acre yields of Wataribune rice obtained in experiments at the Biggs Rice Field Station, in which the crop was submerged to a depth of 6 inches at varying periods after emergence, during the 8-year period from 1914 to 1921, inclusive.

The highest average yield, 3,699 pounds per acre, was obtained by submerging the land 30 days after the rice emerged; submerging the land 60 days after the rice had emerged ranked second, with an average yield of 3,425 pounds per acre; submerging the land 45 days after the rice had emerged ranked third in yield, with 3,379 pounds per acre; and submerging the land 15 days after the rice had emerged produced the lowest average yield, 3,326 pounds per acre. The average yields in the date-of-submergence experiments with rice at the Biggs Rice Field Station from 1914 to 1921, inclusive, are shown graphically in Figure 7.

TABLE 12.—*Annual and average yields obtained in the date-of-submergence experiments with Wataribune rice at the Biggs Rice Field Station, Biggs, Calif., from 1914 to 1921, inclusive.*

Submergence.	Yield per acre when submerged 6 inches (pounds).[1]								
	1914	1915	1916	1917	1918	1919	1920	1921	Average.
15 days after emergence	4,510	3,860	3,750	4,220	3,420	1,700	2,205	2,940	3,326
30 days after emergence	5,610	4,270	4,020	4,500	4,185	2,230	2,450	2,330	3,699
45 days after emergence	5,410	4,100	3,890	4,310	3,240	2,050	2,045	1,990	3,379
60 days after emergence	5,240	3,910	3,610	4,040	4,115	1,980	2,665	[2]1,840	3,425

[1] Yields computed from yields of single fifth-acre plats in 1914, 1915, 1916, 1918, and 1920 and from yields of single tenth-acre plats in 1917, 1919, and 1921.
[2] Plat grassy.

DEPTH OF SUBMERGENCE.

Table 13 shows the yields obtained from the depth-of-submergence irrigation experiment during the 8-year period from 1914 to 1921, inclusive. Each year, 30 days after the rice had emerged, plats were submerged to depths of 2, 4, 6, and 8 inches, respectively. In 1914, 1915, 1917, 1919, and 1921 the highest yield was obtained by submerging the land 6 inches deep during the submergence period. In 1916 and 1920 the highest yield was obtained by submerging the land 8 inches deep during the submergence period. In 1918 the

highest yield was obtained by submerging the land 2 inches deep during the period of submergence.

The highest average yield, 3,925 pounds per acre, was obtained by submerging the land 6 inches deep throughout the submergence period. The average yields in the depth-of-submergence experiments are shown graphically in Figure 8.

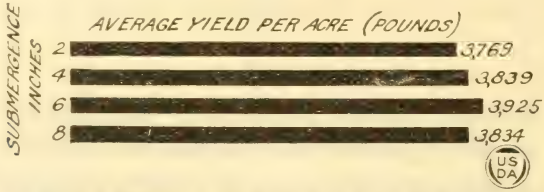

FIG. 8.—Average acre yields of Wataribune rice obtained in the depth-of-submergence experiments at the Biggs Rice Field Station during the 8-year period from 1914 to 1921, inclusive.

The average increase in yield of the 6-inch submergence over the 4-inch submergence was 86 pounds per acre; over the 8-inch submergence, 91 pounds per acre; and over the 2-inch submergence, 156 pounds per acre. These are small average increases. However, in 1914 and 1915 on new and second-year land there was a distinct advantage from holding deep rather than shallow water. On old land, if water-grass control is not involved, shallow submergence appears to be just about as good as deep submergence. The average yields for the 8-year period show that the 6-inch depth ranks first, the 4-inch depth second, the 8-inch depth third, and the 2-inch depth fourth.

TABLE 13.—*Annual and average yields obtained in the irrigation depth-of-submergence experiments with Wataribune rice at the Biggs Rice Field Station, Biggs, Calif., from 1914 to 1921, inclusive.*

Depth of submergence.	Yield per acre (pounds).[1]								
	1914	1915	1916	1917	1918	1919	1920	1921	Average.
2 inches	5,010	4,030	3,620	4,260	4,635	3,000	2,655	2,940	3,769
4 inches	5,490	4,290	3,760	4,440	4,215	2,990	2,655	2,875	3,839
6 inches	5,670	4,510	3,900	4,520	4,035	3,050	2,435	3,280	3,925
8 inches	5,220	4,400	3,940	4,480	4,015	2,710	2,690	3,220	3,834

[1] Yields from single fifth-acre plats in 1914, 1915, 1916, 1918, and 1920, and from duplicated tenth-acre plats, in 1917, 1919, and 1921.

The data available indicate that on new land the water should be held at least 6 inches deep, while on old land it should be held from 4 to 6 inches deep.

STAGNANT AND SLOWLY CHANGING WATER.

Table 14 shows the yields obtained from the different water treatments during the 8-year period from 1914 to 1921, inclusive. The average yields are shown graphically in Figure 9. During the submergence period, under ordinary conditions water is entering the checks continuously. The quantity of water used, if carefully handled, is just enough to keep the checks submerged to a constant depth. In other words, enough water is entering the field each day to replace that lost by evaporation, transpiration, and seepage.

TABLE 14.—*Annual and average yields obtained by different water treatments with Wataribune rice at the Biggs Rice Field Station, Biggs, Calif., from 1914 to 1921, inclusive.*

Year.	Yield per acre (pounds).[1] Slowly changing water, 6-inch submergence.	Stagnant water, 6-inch submergence.	Fluctuating depth of submergence.	No submergence, but soil kept moist.
1914	4,790	4,940	5,290	2,440
1915	4,210	3,990	4,160	2,480
1916	3,460	3,800	3,690	2,100
1917	[2] 4,230	[2] 4,405	4,360	2,490
1918	3,615	2,550	3,625	2,860
1919	[2] 3,000	[2] 2,600	2,950	1,250
1920	2,075	1,850	2,345	670
1921	[2] 3,070	[2] 2,510	2,990	1,110
Average	3,556	3,331	3,676	1,925

[1] Yields from single fifth-acre plats in 1914, 1915, 1916, 1918, and 1920 and from tenth-acre plats (duplicated where noted) in 1917, 1919, and 1921.
[2] Average of duplicated tenth-acre plats.

The yields presented in Table 14 show that in five of the eight years the plat in which the water was slowly changing gave better yields than the plat that was stagnant. In the stagnant plat water was added about once a week. It is the writer's opinion that the addition of several inches of cold water once a week has had a more detrimental effect on the stagnant plat than the stagnant condition itself.

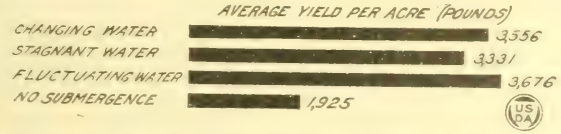

FIG. 9.—Average acre yields of Wataribune rice obtained in experiments to determine the effect of different methods of irrigation at the Biggs Rice Field Station during the 8-year period from 1914 to 1921, inclusive.

FLUCTUATION OF DEPTH OF SUBMERGENCE.

The plan of the experiment in fluctuating the depth of water was to submerge the land 30 days after emergence to a depth of 4 to 6 inches and maintain this depth until the plants began to boot; then to lower the water to 1 to 2 inches and hold it at this depth until the first heads appeared, at which time the water was increased to the usual depth of 4 to 6 inches and held until the crop was mature or ready to drain.

The plats on which the depth of water was changed from time to time yielded less than those submerged 2, 4, 6, and 8 inches deep during the entire submergence period (Table 13). However, it does not appear that the fluctuation of depth of water is nearly as harmful as is commonly believed. Annual and average yields are shown in Table 14.

NO SUBMERGENCE.

On one plat each year the land was kept moist at all times, but no water was held on it during the usual submergence period. The yields from this method of irrigation have ranged from 670 pounds

per acre, in 1920, to 2,860 pounds per acre, in 1918. The average yield for the 8-year period was 1,925 pounds per acre (Table 14). Rice grown in this way stools less than that grown on submerged land, does not grow as tall, has shorter and fewer heads per plant, is not as vigorous, and produces grain of inferior quality. This method of irrigating rice should not be attempted commercially in California, because plenty of water for irrigation and submergence is essential for successful rice production.

FERTILIZER EXPERIMENTS.

For many years previous to the introduction of rice growing, the Stockton clay adobe soil in the Gridley and Biggs area was used for dry-land grain farming, pasture, and hay production. The 18 to 36 inches of black surface soil rest upon a gray calcareous hardpan which is practically impervious to water. No leguminous crops do well on this soil, and for that reason the limiting element in crop production is likely to be nitrogen.

Loughridge [6] shows the humus and humus nitrogen of California soils to be as stated in Table 15.

TABLE 15.—*Humus and humus nitrogen in the soil of the Sacramento Valley.*

Nature of soil.	Soil content (per cent).						
	Humus.					Humus nitrogen.	
	First foot.	Upper 3 feet.		12 feet.		First foot.	Upper 3 feet.
		Average per foot.	Sum.	Average per foot.	Sum.		
Alluvial soils	1.47	0.92	2.76	0.67	7.50	0.08	0.06
Black clay adobe	1.16	.73	2.20	.31	3.62	.06	.04
Gray clay loams	.95	.77	2.39	.42	5.02	.05	.05
Red mesa lands	.47	.30	.90	.15	1.43	.03	.02

Doctor Loughridge comments on the humus content of Sacramento Valley soils as follows:

It would naturally be supposed that because of their deep color the black clay adobe soils would contain more humus than any other soil, but the above results show that such is not the case, for the alluvial soils are richer, and even the gray loams have nearly as much as the black adobe in the first foot and are a little richer in the rest of the column. The color of a soil, then, is no certain guide as to the relative amount of humus it contains. Humification is retarded in close compact adobe clays, and the amount of humus is less than in lighter loam and sandy soils.

Fertilizer experiments were started at Biggs in the spring of 1914. The original plan followed during 1914, 1915, and 1916 was to apply the fertilizer to the land before seeding. In 1917 the plan was changed, and the fertilizers were applied at three dates during the growth of the rice crop, namely, (*a*) when the rice was 3 inches in height, (*b*) when the heads were emerging, and (*c*) two weeks after the first heads appeared. This plan was followed during 1917, 1918, and 1919.

[6] Loughridge, R. H. Humus in California soils. Calif. Agr. Exp. Sta. Bul. 242, p. 62. 1914.

As two plans have been followed in the fertilizer experiments, it is thought best to discuss the results obtained under each plan separately and then to consider the combined results of both plans.

EXPERIMENTS, 1914 TO 1916.

The arrangement of the plats and the quantities of the various fertilizers used from 1914 to 1916 were as follows:

Plats 101 and 201.	Check; no fertilizer.
102 and 202.	Acid phosphate, 350 pounds.
103 and 203.	Check; no fertilizer.
104 and 204.	Sulphate of ammonia, 100 pounds.
105 and 205.	Nitrate of soda, 100 pounds.
106 and 206.	Cottonseed meal, 280 pounds.
107 and 207.	Check; no fertilizer.
108 and 208.	Dried blood, 160 pounds.
109 and 209.	Sulphate of potash, 100 pounds.
110 and 210.	Acid phosphate, 350 pounds; sulphate of ammonia, 100 pounds.
111 and 211.	Check; no fertilizer.
112 and 212.	Acid phosphate, 350 pounds; sulphate of potash, 100 pounds.
113 and 213.	Sulphate of ammonia, 100 pounds; sulphate of potash, 100 pounds.
114 and 214.	Acid phosphate, 350 pounds; sulphate of ammonia, 100 pounds; sulphate of potash, 100 pounds.
115 and 215.	Check; no fertilizer.
116 and 216.	Lime, 2,000 pounds.
117 and 217.	Manure, 2,000 pounds.
118 and 218.	Check; no fertilizer.

The annual and average costs per ton of the fertilizers used during the six years, 1914 to 1919, are shown in Table 16. The average cost of fertilizers per acre when applied according to the foregoing outline is shown in column 3 of Table 17.

The yields obtained from the fertilizer experiments during the 3-year period from 1914 to 1916, inclusive, are shown in Table 18. These are the average yields each year from 2 tenth-acre plats, except the check, which represents the average yield of 12 tenth-acre plats each year.

TABLE 16.—*Annual and average prices per ton of fertilizers at San Francisco, Calif., during the 6-year period from 1914 to 1919, inclusive.*

Fertilizer.	Cost per ton.						Average.		
	1914	1915	1916	1917	1918	1919	1914 to 1916.	1917 to 1919.	1914 to 1919.
Manure (obtained locally)	$4.00	$4.00	$4.00	$5.00	$6.00	$6.50	$4.00	$5.83	$4.92
Dried blood	51.30	51.50	51.25	70.00	110.00	120.00	51.35	100.00	75.67
Sulphate of ammonia	65.50	65.00	66.00	95.00	135.00	120.00	65.50	116.67	91.08
Cottonseed meal	35.00	35.00	42.00				37.33		
Nitrate of soda	44.00	40.00	37.00	71.00	90.00	100.00	40.33	87.00	63.67
Sulphate of potash	58.30	56.03	69.55	200.00	200.00	200.00	61.29	200.00	130.65
Acid phosphate	12.25	12.50	12.80	17.50	20.00	26.00	12.52	21.17	16.84
Lime (obtained locally)	12.00	12.00	12.00	15.00	15.00	15.00	12.00	15.00	13.50

The fertilizer experiments in 1914 were conducted on second-year land, in 1915 on third-year land, and in 1916 on fourth-year land. Each year the land was fall-plowed, and the following spring it was well prepared before seeding.

TABLE 17.—*Average cost per acre of fertilizers at San Francisco, Calif., in the 3-year periods from 1914 to 1916 and 1917 to 1919 and for the 6-year period from 1914 to 1919, inclusive.*

Fertilizer.	Applied per acre (pounds).	Average cost per acre.		
		1914 to 1916.	1917 to 1919.	1914 to 1919.
1	2	3	4	5
Acid phosphate	350	$2.19	$3.70	$2.95
Sulphate of ammonia	100	3.28	5.83	4.55
Nitrate of soda [1]	120	2.02	5.22	3.62
Cottonseed meal	280	5.23	.....	.....
Dried blood	160	4.11	8.00	6.05
Sulphate of potash	100	3.06	10.00	6.53
Acid phosphate	350	5.47	9.53	7.50
Sulphate of ammonia	100			
Acid phosphate	350	5.25	13.70	9.48
Sulphate of potash	100			
Sulphate of ammonia	100	6.34	15.83	11.08
Sulphate of potash	100			
Acid phosphate	350	8.53	19.53	14.03
Sulphate of ammonia	100			
Sulphate of potash	100			
Lime (obtained locally)	2,000	12.00	15.00	13.50
Manure (obtained locally)	2,000	4.00	5.83	4.92

[1] Applied at the rate of 100 pounds from 1914 to 1916 and 120 pounds from 1917 to 1919.

TABLE 18.—*Annual and average yields of Wataribune rice obtained in the fertilizer experiments at the Biggs Rice Field Station, Biggs, Calif., in the 3-year period from 1914 to 1916, inclusive, with average increase or decrease in yields and net values due to fertilizers.*

Fertilizer.	Yield per acre (pounds).				Gain or loss per acre.	
	1914	1915	1916	Average.	Pounds.	Net value.[1]
Manure	4,230	5,000	4,235	4,488	+879	+$12.70
Sulphate of ammonia	4,375	4,580	3,825	4,260	+651	+9.09
Dried blood	4,375	4,485	3,905	4,255	+646	+8.16
Cottonseed meal	4,610	4,335	3,630	4,192	+583	+5.85
Nitrate of soda	3,995	4,225	3,165	3,795	+186	+1.51
Acid phosphate	3,810	4,240	3,870	3,973	+364	+1.45
Sulphate of ammonia						
Sulphate of potash	4,270	4,025	3,200	3,832	+223	+1.18
Check [2]	3,692	3,914	3,221	3,609	.....	.....
Sulphate of potash	3,850	4,420	3,490	3,920	+311	−.43
Sulphate of ammonia						
Acid phosphate	3,795	4,055	3,040	3,630	+21	−1.79
Acid phosphate	3,755	4,315	3,580	3,883	+274	−3.32
Sulphate of potash						
Sulphate of ammonia						
Acid phosphate	2,990	4,275	3,415	3,560	−49	−6.18
Sulphate of potash						
Lime	3,130	3,750	3,085	3,322	−287	−17.45

[1] The average price of rice from 1914 to 1916 was $1.90 per 100 pounds. The figures in this column represent the value of the increased production at this price, less the cost of fertilizers at San Francisco (Table 17), but do not take into account the freight, the cost of application, or the extra cost of handling the increased crop.

[2] Average yield from 12 tenth-acre plats each year.

As shown in Table 18 all except two of the fertilizers applied have resulted in increased average yields, ranging from 21 pounds per acre for acid phosphate to 879 pounds per acre for manure. The average increase in annual yield in the 3-year period from applying manure was 879 pounds; sulphate of ammonia, 651 pounds; dried blood, 646 pounds; and cottonseed meal, 583 pounds per acre. The application of lime resulted in a reduced yield, as did the use of acid phosphate and sulphate of potash in combination.

The average yields obtained in the fertilizer experiments with rice at the Biggs Rice Field Station from 1914 to 1916, inclusive, are shown graphically in Figure 10.

The average price received for rough rice during the 3-year period from 1914 to 1916 was $1.90 per 100 pounds. By deducting the cost per acre of the fertilizers and not including any charge for applying them, the increases show an average profit of $12.70 per

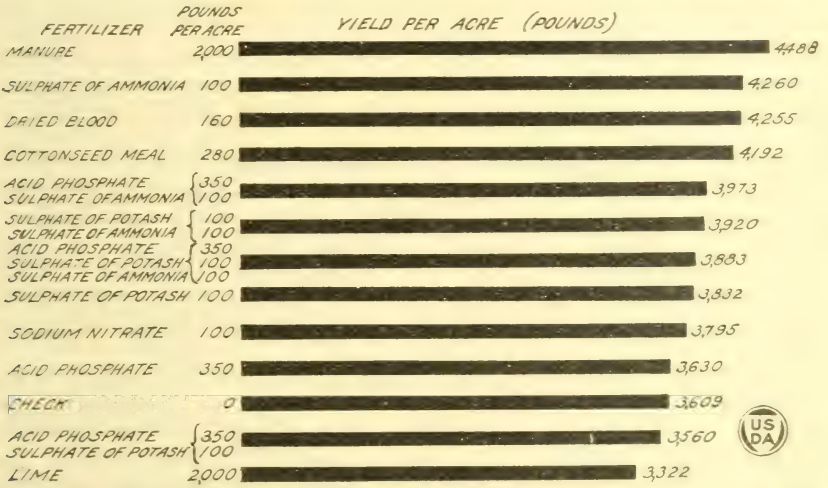

FIG. 10.—Average acre yields of Wataribune rice obtained in the fertilizer experiments at the Biggs Rice Field Station in the 3-year period from 1914 to 1916, inclusive.

acre resulting from the application of manure, $9.09 per acre from sulphate of ammonia, $8.16 from dried blood, and $5.85 per acre from cottonseed meal. The fertilizers used, with the exception of manure and lime, could be applied at seeding time with a fertilizer attachment without appreciable cost.

Other fertilizers and combinations have increased yields, but the increase has not been enough to cover the cost of the fertilizers. For example, sulphate of ammonia and sulphate of potash when applied in combination increased the average yield 311 pounds per acre, but the cost per acre of the fertilizer was more than the value of the additional crop.

Manure, sulphate of ammonia, dried blood, and cottonseed meal have improved the color and vigor as well as increased the yield of the rice crop at the Biggs Rice Field Station during the 3-year period from 1914 to 1916, the net profit ranging from $5.85 per acre for cottonseed meal to $12.70 per acre for manure.

EXPERIMENTS, 1917 TO 1919.

The arrangement of the plats and the quantities of fertilizers applied per acre during the 3-year period from 1917 to 1919, inclusive, are shown in Figure 11. The three stages at which fertilizers were applied are designated as the A stage, when the plants were 3 inches high; B stage, when the first heads were emerging; and the C stage, two weeks after the first heads had emerged.

The cost per ton of the fertilizers used each year and the average cost per ton for the three years (1917 to 1919) are shown in Table 16. The cost of fertilizers per acre when applied according to the outline in Figure 11 was as shown in column 4 of Table 17. The yields obtained from the fertilizer experiments during the 3-year period from 1917 to 1919 are shown in Table 19. These are yields from single tenth-acre plats each year, except the check, which represents seven tenth-acre plats annually.

In 1917 the fertilizer experiments were conducted on land that had produced four consecutive rice crops; in 1918, on land that had produced five consecutive rice crops; and in 1919 on land that had produced six successive rice crops. The land was fall-plowed each year except in 1918 and well prepared before seeding the following spring.

The fertilizer experiments as conducted from 1917 to 1919 were for the purpose of determining the effect of applications of various fertilizers at different stages of growth on the yield and quality of the resulting crop. Obviously, it would be impractical to apply fertilizers in the field at any of the three stages of growth at which they were applied in this experiment, viz, when the rice was 3 inches high, when the heads were emerging, and two weeks after first heading.

The fertilizers used, except nitrate of soda, acid phosphate, and sulphate of potash combined with acid phosphate, produced higher average yields when applied when the rice was 3 inches high than when applied at either of the later stages. The plat to which acid phosphate alone was applied when the heads were emerging produced exactly the same average yield as the one to which the phosphate was added when the plants were 3 inches high, while the plat to which both sulphate of potash and acid phosphate were applied two weeks after first heading averaged more than either of the two fertilized earlier. With this latter exception, all the plats to which fertilizer was added at first heading outyielded those to which it was added two weeks later. These results show quite clearly that the earlier the fertilizers are applied, the higher the average yields have been except when nitrate of soda was used. This fertilizer is very soluble and is likely to be carried away with the drainage water if applied early.

The annual and average yields obtained from the plats to which fertilizers were added when the plants were 3 inches high are shown in Table 20, with the average annual gain or loss in pounds of rice and in dollars, as compared with the check plats. Only the actual cost of the fertilizers is taken into account, the freight from San Francisco, the cost of application, and the extra cost of handling the increased crop, if any, not being included.

101. Check; no fertilizer.	201. Acid phosphate, 350 pounds. B stage.
102. Acid phosphate, 350 pounds. A stage.	202. Acid phosphate, 350 pounds. C stage.
103. Sulphate of ammonia, 100 pounds. C stage.	203. Check; no fertilizer.
104. Sulphate of ammonia, 100 pounds. A stage.	204. Sulphate of ammonia, 100 pounds. B stage.
105. Nitrate of soda, 120 pounds. A stage.	205. Nitrate of soda, 120 pounds. B stage.
106. Check; no fertilizer.	206. Check; no fertilizer.
107. Check; no fertilizer.	207. Sulphate of potash, 100 pounds. C stage.
108. Dried blood, 160 pounds. A stage.	208. Dried blood, 160 pounds. B stage.
109. Sulphate of potash, 100 pounds. A stage.	209. Sulphate of potash, 100 pounds. B stage.
110. Acid phosphate, 350 pounds; sulphate of ammonia, 100 pounds. A stage.	210. Acid phosphate, 350 pounds; sulphate of ammonia, 100 pounds. B stage.
111. Acid phosphate, 350 pounds; sulphate of ammonia, 100 pounds. C stage.	211. Check; no fertilizer.
112. Acid phosphate, 350 pounds; sulphate of potash, 100 pounds. A stage.	212. Acid phosphate, 350 pounds; sulphate of potash, 100 pounds. B stage.
113. Sulphate of ammonia, 100 pounds; sulphate of potash, 100 pounds. A stage.	213. Sulphate of ammonia, 100 pounds; sulphate of potash, 100 pounds. B stage.
114. Acid phosphate, 350 pounds; sulphate of potash, 100 pounds; sulphate of ammonia, 100 pounds. A stage.	214. Acid phosphate, 350 pounds; sulphate of potash, 100 pounds; sulphate of ammonia, 100 pounds. B stage.
115. Acid phosphate, 350 pounds; sulphate of potash, 100 pounds. C stage.	215. Acid phosphate, 350 pounds; sulphate of potash, 100 pounds; sulphate of ammonia, 100 pounds. C stage.
116. Lime, 2,000 pounds. A stage.	216. Lime, 2,000 pounds. B stage.
117. Manure, 2,000 pounds. A stage.	217. Manure, 2,000 pounds. B stage.
118. Sulphate of ammonia, 100 pounds; sulphate of potash, 100 pounds. C stage.	218. Check; no fertilizer.

FIG. 11.—Arrangement of plats, quantity of fertilizer applied, and stage of application in the fertilizer experiments with Wataribune rice at the Biggs Rice Field Station, Biggs, Calif., during the 3-year period from 1917 to 1919, inclusive.

TABLE 19.—*Annual and average yields of Wataribune rice obtained in fertilizer experiments at the Biggs Rice Field Station, Biggs, Calif., during the 3-year period from 1917 to 1919, inclusive.*

Fertilizer.	Yields per acre when fertilizer was applied at different stages (pounds).											
	A stage, plants 3 inches high.				B stage, first heads appearing.				C stage, 2 weeks after first heading.			
	1917	1918	1919	Average.	1917	1918	1919	Average.	1917	1918	1919	Average.
Manure	3,960	4,720	3,150	3,943	4,040	3,020	2,830	3,297	.....	.....	.....	.....
Sulphate of ammonia	4,360	3,910	2,210	3,493	3,650	3,560	1,950	3,053	3,740	2,930	1,530	2,733
Sulphate of ammonia Acid phosphate	4,240	3,640	2,550	3,477	3,960	3,480	1,980	3,140	3,690	3,080	1,680	2,817
Dried blood	4,200	3,720	2,100	3,340	3,820	3,310	2,080	3,070	.....	.....	.....	.....
Sulphate of ammonia Sulphate of potash Acid phosphate	4,020	3,770	1,930	3,240	3,690	3,620	1,820	3,043	3,500	2,340	1,470	2,437
Sulphate of ammonia Sulphate of potash	3,890	3,490	1,900	3,093	3,720	3,460	1,950	3,043	3,530	2,470	1,850	2,617
Sulphate of potash	3,730	3,190	1,930	2,950	3,690	2,500	1,850	2,680	3,650	2,280	1,830	2,587
Acid phosphate	3,520	3,500	1,600	2,873	3,560	3,260	1,800	2,873	3,690	3,140	1,450	2,760
Nitrate of soda	3,520	3,280	1,750	2,850	3,820	3,260	2,750	3,277	.....	.....	.....	.....
Sulphate of potash Acid phosphate	3,530	3,280	1,680	2,830	3,480	2,710	1,450	2,547	3,790	3,230	2,100	3,040
Lime	3,390	1,760	1,850	2,333	3,580	1,390	1,880	2,283	.....	.....	.....	.....
No fertilizer [1]	3,690	2,706	1,799	2,732	.....	.....	.....	.....	.....	.....	.....	.....

[1] Average yields from 7 tenth-acre plats.

The average increase in annual yield from applications of manure applied when the rice plants were 3 inches high was 1,211 pounds: sulphate of ammonia, 761 pounds; sulphate of ammonia and acid phosphate in combination, 745 pounds; dried blood, 608 pounds; and sulphate of ammonia, sulphate of potash, and acid phosphate in combination, 508 pounds per acre. Lime did not increase the average yield, but actually caused a reduction in yield of 399 pounds to the acre.

The average price paid for rough rice during the years 1917 to 1919 was $4.90 per 100 pounds. By deducting the cost of the fertilizers applied, with no charge for application, the increased yields from fertilizers show acre profits for this period ranging from 56 cents for sodium nitrate to $53.51 for manure. The application of lime and of sulphate of potash combined with acid phosphate caused annual losses of $34.55 and $8.90, respectively.

The increased yield from the use of sulphate of ammonia was worth $31.46 per acre, acid phosphate and sulphate of ammonia combined, $26.98 per acre, and dried blood, $21.79 per acre.

TABLE 20.—*Annual and average yields of Wataribune rice obtained in the fertilizer experiments at the Biggs Rice Field Station, Biggs, Calif., in the 3-year period from 1917 to 1919, inclusive, with the average increase or decrease in yields and net values due to fertilizers.*[1]

Fertilizer.	Yield per acre (pounds).				Gain or loss per acre.	
	1917	1918	1919	Average.	Pounds.	Net value.[2]
Manure	3,960	4,720	3,150	3,943	+1,211	+$53.51
Sulphate of ammonia	4,360	3,910	2,210	3,493	+761	+31.46
Sulphate of ammonia Acid phosphate	4,240	3,640	2,550	3,477	+745	+26.98
Dried blood	4,200	3,720	2,100	3,340	+608	+21.79
Sulphate of ammonia Sulphate of potash Acid phosphate	4,020	3,770	1,930	3,240	+508	+5.36
Acid phosphate	3,520	3,500	1,600	2,873	+141	+3.21
Sulphate of ammonia Sulphate of potash	3,890	3,490	1,900	3,093	+361	+1.86
Sulphate of potash	3,730	3,190	1,930	2,950	+218	+.68
Nitrate of soda	3,520	3,280	1,750	2,850	+118	+.56
No fertilizer[3]	3,690	2,706	1,799	2,732	.....	.....
Sulphate of potash Acid phosphate	3,530	3,280	1,680	2,830	+98	−8.90
Lime	3,390	1,760	1,850	2,333	−399	−34.55

[1] Yields from tenth-acre plats, fertilizer applied when the rice plants were approximately 3 inches high.
[2] The average price of rice for 1917, 1918, and 1919 was $4.90 per 100 pounds. This column shows the value of the additional crop less the actual cost of fertilizers. The cost of freight on fertilizers, the cost of application, and the extra cost of handling the additional crop are not taken into account.
[3] Average yields from 7 tenth-acre plats.

SUMMARY OF FERTILIZER EXPERIMENTS.

Table 21 shows the average yields obtained each year in the fertilizer experiments, the average yields for the 6-year period from 1914 to 1919, the increase or decrease in yield as compared with the check, and the value of this increase or decrease.

The average increase in yield from the fertilizers ranges from 25 pounds for acid phosphate and sulphate of potash combined to 1,046 pounds per acre for manure. The application of lime caused an average decrease in yield of 342 pounds. Manure produced the largest increase in yield and net value per acre. Sulphate of ammonia ranked second, dried blood ranked third, and acid phosphate and sulphate of ammonia combined ranked fourth in both increase and net return. Acid phosphate alone, acid phosphate and sulphate of potash combined, and the combination of sulphate of ammonia, sulphate of potash, and acid phosphate, while causing increases in yield, cost more than the additional crop was worth.

It should be remembered that the increases in yield due to the various fertilizers have been multiplied by the average price of rough rice ($3.40 per 100 pounds) for the period under discussion (1914 to 1919). This average price no doubt is much higher than it would have been or will be during normal times, and therefore the net returns per acre from the use of the various fertilizers as shown in Table 21 are much higher than one should expect when conditions return to normal.

TABLE 21.—*Annual and average yields of Wataribune rice obtained in the fertilizer experiments at the Biggs Rice Field Station, Biggs, Calif., in the 6-year period from 1914 to 1919, inclusive, with the average increase or decrease in yields and net values due to fertilizers.*

Fertilizer.	Yield per acre (pounds).							Gain or loss per acre.	
	1914 [1]	1915 [1]	1916 [1]	1917 [2]	1918 [2]	1919 [2]	Average.	Pounds.	Net value.[3]
Manure	4,230	5,000	4,235	3,960	4,720	3,150	4,216	+1,046	+$30.64
Sulphate of ammonia	4,375	4,580	3,825	4,360	3,910	2,210	3,877	+707	+19.49
Dried blood	4,375	4,485	3,905	4,200	3,720	2,100	3,798	+628	+15.30
Sulphate of ammonia Acid phosphate	3,810	4,240	3,870	4,240	3,640	2,550	3,725	+555	+11.37
Nitrate of soda	3,995	4,225	3,165	3,520	3,280	1,750	3,323	+153	+1.58
Sulphate of potash	4,270	4,025	3,200	3,700	3,190	1,930	3,386	+216	+.81
Sulphate of ammonia Sulphate of potash	3,850	4,420	3,490	3,890	3,490	1,900	3,507	+337	+.38
No fertilizer	[4] 3,692	[4] 3,914	[4] 3,221	[5] 3,690	[5] 2,706	[5] 1,799	3,170	.....	.....
Acid phosphate	3,795	4,055	3,040	3,520	3,500	1,600	3,252	+82	−.16
Sulphate of ammonia Sulphate of potash Acid phosphate	3,755	4,315	3,580	4,020	3,770	1,930	3,562	+392	−.70
Sulphate of potash Acid phosphate	2,990	4,275	3,415	3,530	3,280	1,680	3,195	+25	−8.63
Lime	3,130	3,750	3,085	3,390	1,760	1,850	2,828	−342	−25.13

[1] Average yields from duplicated tenth-acre plats.
[2] Yields from the tenth-acre plats to which fertilizers were applied when the rice was 3 inches high.
[3] The average price of rice from 1914 to 1919, $3.40 per 100 pounds. This column shows simply the value of the increased production less the cost of fertilizers (Table 17), without taking into account the freight on fertilizers, the cost of application, or the cost of handling the increased crop.
[4] Average yields from 12 tenth-acre plats.
[5] Average yields from 7 tenth-acre plats.

The data show that, even under normal conditions, however, manure, sulphate of ammonia, and dried blood increase the yields of rice to a marked extent, and in time sulphate of ammonia or dried blood will probably be used on commercial fields in California if the relative prices of rice and fertilizers justify such use.

Manure is cheap but is difficult to apply. It is scarce and also carries weed seeds. These are the main objections to manure as a fertilizer. Dried blood and sulphate of ammonia can be applied with a fertilizer attachment on the drill at seeding time, and this is a strong point in their favor. There is little difference in the results obtained from dried blood and sulphate of ammonia, but sulphate of ammonia is easier to apply and for this reason should be the more popular on commercial fields.

Table 22 shows the average acre yields obtained from the plats to which various fertilizers were applied in the 3-year period from 1914 to 1916 and also the average yields from the plats to which fertilizers were applied at different stages of growth of the crop in the period from 1917 to 1919. In every case the average yields in the 3-year period from 1917 to 1919 were lower than the yields from the corresponding plats in the earlier period, 1914 to 1916. These lower yields were undoubtedly due to two causes, and it is impossible to say which one of these was the more important. In the earlier period the fertilizer was applied before seeding time and was available to the crop during the entire period of its growth. In the later period it was

applied at three stages of growth, the first stage being when the plants were about 3 inches high. As previously stated, the plats to which fertilizer was applied at this stage in general yielded more than those which were fertilized later. The other and probably the more important factor in reducing crop yields during the second period was the increase in weed growth. The land had been continuously in rice since the beginning of the experiment, and weed growth increased with each successive crop.

TABLE 22.—*Average yields of Wataribune rice obtained in the fertilizer experiments at the Biggs Rice Field Station, Biggs, Calif., in the 3-year periods from 1914 to 1916 and 1917 to 1919, inclusive.*

Fertilizer.	Yield per acre (pounds).			
	1914 to 1916.[1]	1917 to 1919.[2]		
		A stage.[3]	B stage.[4]	C stage.[5]
Manure	4,488	3,943	3,297	
Sulphate of ammonia	4,260	3,493	3,053	2,733
Dried blood	4,255	3,340	3,070	
Cottonseed meal	4,192			
Sulphate of ammonia Acid phosphate	3,973	3,477	3,140	2,817
Sulphate of ammonia Sulphate of potash	3,920	3,093	3,043	2,617
Sulphate of ammonia Sulphate of potash Acid phosphate	3,883	3,240	3,043	2,437
Sulphate of potash	3,832	2,950	2,680	2,587
Nitrate of soda	3,795	2,850	3,277	
Acid phosphate	3,630	2,873	2,873	2,760
Sulphate of potash Acid phosphate	3,560	2,830	2,547	3,080
No fertilizer	[6] 3,609	[7] 2,732		
Lime	3,322	2,333	2,283	

[1] Yields of duplicated tenth-acre plats each year.
[2] Yields of single tenth-acre plats each year.
[3] Fertilizer applied when the rice plants were 3 inches high.
[4] Fertilizer applied when the first heads were emerging.
[5] Fertilizer applied two weeks after first heading.
[6] Average yields from 12 tenth-acre plats each year.
[7] Average yields from 7 tenth-acre plats each year.

VARIETAL EXPERIMENTS.

Thousands of varieties and strains of rice are grown in the various rice-producing countries of the world. One of the principal lines of experimentation at the Biggs Rice Field Station has been the testing of many varieties of rice from various sources in the hope of finding some that are superior in yield and milling quality to those that are now being grown commercially in California.

CLASSES OF RICE.

The varieties of rice most commonly grown in the United States are classed roughly as long-grain, medium-grain, and short-grain. The short-grain rices have small stalks, narrow leaves, and short kernels. The medium-grain rices have rather large stalks, comparatively wide leaves, and kernels of medium length. The long-grain rices have

large stalks, wide leaves, and long kernels. The short-grain and medium-grain rices usually stool more heavily than the long-grain varieties.

In the Southern States the rice acreage consists largely of medium-grain rices, Blue Rose being the leading variety. The long-grain rices, of which Honduras is the leading variety, rank second in acreage. Only a small acreage in Louisiana, Texas, and Arkansas is devoted to the short-grain rices, of which Wataribune is the leading variety. In California about 98 per cent of the rice crop is of the short-grain varieties. Many varieties of long-grain, medium-grain, and short-grain rice have been tested for a number of years in comparative experiments at the Biggs Rice Field Station.

VARIETIES GROWN ON TENTH-ACRE PLATS.

Table 23 shows the yields of 35 varieties and strains of rice grown at the Biggs Rice Field Station during the 9-year period from 1913 to 1921, inclusive. In 1913, 1914, and 1915 the varietal experiment was conducted on new land, in 1916 and 1917 on fallowed land that had produced one crop of rice, in 1918 and 1919 on fallowed land that had produced two crops of rice, and in 1920 and 1921 on fallowed land that had produced three crops of rice. The seed bed and stands were good each year. During the 9-year period from 1913 to 1921, inclusive, 27 varieties and strains of short-grain rice were grown, 4 of medium-grain rice, and 4 of long-grain rice. The short-grain and medium-grain rices are grouped into early, midseason, and late varieties, and the long-grain rices into midseason and late varieties.

The 35 varieties grown during the 9-year period from 1913 to 1921, inclusive, are grouped as follows:

Short grain:
- Early group.—Spagnuolo (C. I. Nos. 1582 and 1585), Novarese (C. I. No. 1598), Colusa (C. I. No. 1600), C. I. No. 1992, Swamp (C. I. No. 2008), Benlloch (C. I. No. 2052), and Sue Hero.
- Midseason group.—Butte (C. I. No. 1564), Fukuyama (C. I. No. 2293), Kokuryo-Miyako (C. I. No. 2335), and Selections Nos. 161, 175, 204, 209 (Tokyo), 1561–1 (Caloro), 1561–2, 1561–3, and 1561–4.
- Late group.—Makuno Uchi (C. I. No. 1308), Wataribune (C. I. No. 1561), Omachi (C. I. No. 1573), Shinriki (C. I. No. 1642), Takenari (C. I. No. 2295), Tse-Nishiki (C. I. No. 2332), and Selections Nos. 114 and 115.

Medium grain:
- Early group.—Pilit (C. I. No. 81).
- Midseason group.—Early Prolific.
- Late group.—C. I. Nos. 1241 and 1258.

Long grain:
- Midseason group.—Selection No. 113.
- Late group.—Honduras (C. I. No. 1643), Carolina White (C. I. No. 1644), and Carolina Gold (C. I. No. 1645).

In favorable years the long-grain varieties yield well, but they are not as well adapted to California conditions as the short-grain rices.

During the 3-year period from 1913 to 1915, inclusive, when grown on new land the short-grain group, represented by Wataribune, produced the highest average yields; the short-grain midseason group, represented by Butte, ranked second; the medium-grain early group, represented by Pilit, ranked third; the long-grain late group, represented by Carolina Gold, ranked fourth; and the short-grain early group, represented by Spagnuolo, ranked fifth in average yield per acre.

ABLE 23.—*Annual and average yields of 35 varieties and strains of rice grown at the Biggs Rice Field Station, Biggs, Calif., during the 9-year period from 1913 to 1921, inclusive.*

Type, group, and variety	C. I. No.	Yield per acre (pounds).												
		1913	1914	1915	1916	1917	1918	1919	1920	1921	Average. 1913 to 1915.	1914 to 1918.	1918 to 1921.	1913 to 1921.
SHORT GRAIN.														
Early group—														
Spagnuolo	1582	4,200	2,400	3,200							3,267			
Do	1585	3,401	3,675	2,980	1,700	2,210	2,080				3,352	2,529		
Novarese	1598	3,598	2,400	2,930	1,930	2,030					2,976			
Colusa	1600		3,589	[1] 3,280	[1] 3,307	4,000	2,320	1,500	1,750	1,730		3,299	1,825	
Unnamed	1992					3,280	1,620	1,600						
Swamp	2008					3,360	2,500	1,350						
Benlloch	2052					3,190	2,540	1,700						
Sue Hero							3,952	2,130	[2] 890	[2] 400			1,843	
Midseason group—														
Caloro	1561–1						[3] 5,439	3,904	1,730	[1] 2,610			3,421	
Wataribune selection	1561–2						[3] 4,863	2,805	2,020	3,010			3,174	
Do	1561–3						[3] 5,949	3,960	2,640	3,130			3,920	
Do	1561–4						[3] 5,604	2,860	2,550	2,900			3,479	
Butte	1564	4,500	5,010	[1] 5,593	[1] 3,800	4,540	1,510	2,220	1,830	2,100	5,034	4,091	1,915	3,456
Fukuyama	2293							2,600	1,820	2,460				
Kokuryo-Miyako	2335						2,510	2,900	2,000	2,210			2,405	
Selection No. 161							3,090	3,320	1,820	2,700			2,732	
Selection No. 175								3,250	2,150	2,890				
Selection No. 204							3,000	2,800	2,340	2,310			2,612	
Tokyo, Selection No. 209							4,500	2,650	2,150	2,980			3,070	
Late group—														
Makuno Uchi	1308	3,300	6,230	5,360							4,963			
Wataribune	1561	5,350	6,650	6,870	4,420	[4] 4,905	[3] 3,435	[5] 2,854	[4] 2,410	2,380	6,290	5,256	2,770	4,364
Omachi	1573	5,250	[6] 6,555	6,480	4,280	4,500	2,910	2,610	2,530	2,890	6,095	4,945	2,735	4,223
Shinriki	1642	5,420	6,730	6,020	3,990	4,220	2,730	2,790	[6] 1,780	2,500	[6] 6,057	4,738	2,450	4,020
Takenari	2295							2,330	2,450	2,150				
Tse-Nishiki	2332						2,140	3,100	2,590	2,420			2,562	
Selection No. 114							2,900	3,870	2,690	2,520			2,995	
Selection No. 115							2,680	3,250	3,140	2,910			2,995	
MEDIUM GRAIN.														
Early group—														
Pilit	81	3,550	4,450	[4] 4,580	3,300	3,470	1,630				4,193	3,486		
Midseason group—														
Early Prolific							2,370	3,260	1,680	2,040			2,337	
Late group—														
From Ceylon	1241		3,500	[1] 2,677	[1] 1,920	2,590	2,450					2,627		
Do	1258		4,320	3,690	[1] 2,147	3,040	2,220					3,083		
LONG GRAIN.														
Midseason group—														
Selection No. 113							2,600	3,200	2,250	2,400			2,612	
Late group—														
Honduras	1643	3,240	2,930	3,720	2,200	3,050	2,620	2,350	1,580	1,710	3,297	2,904	2,065	2,609
Carolina White	1644	3,600	[4] 3,975	3,945	2,130	3,200	2,820	2,150	1,120	1,350	3,840	3,214	1,800	2,699
Carolina Gold	1645	4,300	[4] 3,555	3,750	1,850	2,840	2,570	3,280	850	1,650	3,868	2,913	2,088	2,735

[1] Average yields from 3 tenth-acre plats.
[2] Damaged by birds.
[3] Yields from one-third acre plats.
[4] Average yields from 2 tenth-acre plats.
[5] Average yields from 4 tenth-acre plats.
[6] Not fully mature when harvested.

During the 3-year period from 1917 to 1919, inclusive, when grown on second and third year land, the short-grain late group, represented by Wataribune, produced the highest average yields; the long-grain late group, represented by Carolina Gold, ranked second; the short-grain midseason group, represented by Butte, ranked third; and the short-grain early group, represented by Colusa, ranked fourth in average yield per acre.

During the 3-year period from 1919 to 1921, inclusive, and the 4-year period from 1918 to 1921, inclusive, when grown on third and

fourth year land the short-grain midseason group, represented by Selection No. 1561–3, produced the highest average yield; the short-grain late group, represented by Selection No. 115, ranked second; the long-grain midseason group, represented by Selection No. 113, ranked third; the medium-grain midseason group, represented by Early Prolific, ranked fourth; the long-grain late group, represented by Carolina Gold, ranked fifth; and the short-grain early group, represented by Colusa, ranked sixth in average yield per acre.

During the 5-year period from 1914 to 1918, inclusive, the short-grain late group, represented by Wataribune, gave the highest average yield; the short-grain midseason group, represented by Butte, ranked second; the medium-grain early group, represented by Pilit, ranked third; the short-grain early group, represented by

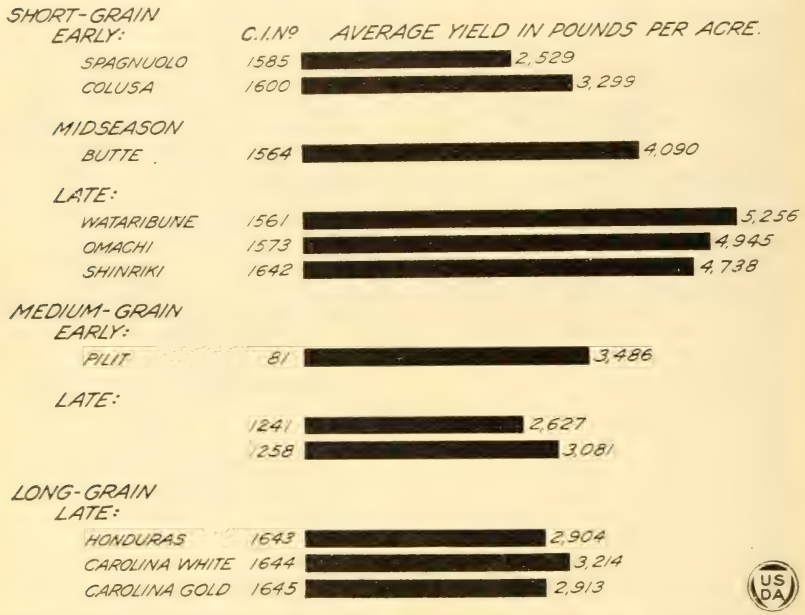

FIG. 12.—Average acre yields of 12 varieties of rice grown at the Biggs Rice Field Station during the 9-year period from 1913 to 1921, inclusive.

Colusa, ranked fourth; the long-grain late group, represented by Carolina White, ranked fifth; and the medium-grain late group, represented by C. I. No. 1258, ranked sixth. The average yields of 12 varieties of rice grown at the Biggs Rice Field Station from 1914 to 1918, inclusive, are shown graphically in Figure 12.

During the 9-year period from 1913 to 1921, inclusive, the short-grain late varieties, Wataribune, Omachi, and Shinriki, produced higher average yields than the short-grain midseason Butte variety. Butte, however, has yielded better than any of the long-grain late varieties, Carolina Gold, Carolina White, or Honduras.

The highest yields of rice are obtained on new or first-year land, a marked decrease in yields usually occurring with each successive crop year. During the 3-year period from 1913 to 1915, inclusive, the Wataribune variety produced an average yield of 6,290 pounds per acre on new land; for the 3-year period from 1917 to 1919,

inclusive, Wataribune produced an average yield of 3,731 pounds per acre on second and third year fallow land; and for the 3-year period from 1919 to 1921, inclusive, Wataribune produced an average yield of 2,548 pounds per acre on third and fourth year fallow land. Other varieties show similar decreases in yield on old land. Therefore, in comparing varieties it is necessary to compare them for the same years and when grown on land that has produced the same number of rice crops.

The average yields for the 4-year period from 1918 to 1921, inclusive, on old land show that the short-grain midseason varieties rank first in yield and the short-grain late varieties second. The long-grain midseason Selection No. 113, the medium-grain midseason Early Prolific, the long-grain late Carolina Gold, and the short-grain early Colusa, follow in order.

The leading commercial variety at present is Early Wataribune, a short-grain midseason variety. Next in importance are the short-grain early varieties, Colusa (C. I. No. 1600) and Onsen, while the short-grain late variety, Wataribune, is third. The Wataribune is grown on old land, the Early Wataribune and Caloro on new and old land, and Colusa (C. I. No. 1600) and Onsen largely on new land, as they do not yield well on old land unless it is very rich. There is a very small annual acreage devoted to the medium-grain Early Prolific and long-grain Edith varieties in California.

TABLE 24.—*Average agronomic data for 12 varieties of rice grown at the Biggs Rice Field Station, Biggs, Calif., during the 8-year period from 1913 to 1920, inclusive.*

[Average date of first irrigation for all varieties, April 26; average date of emergence, May 14.]

Type, group, and variety.	C. I. No.	Date of—				Height (inches).	From first irrigation to maturity (days).
		Seeding.	Heading.	Ripening.	Harvesting.		
Short grain:							
Early group—							
Spagnuolo (locally known as Italian rice)	1585	Apr. 20	Aug. 5	Sept. 8	Sept. 9	35	135
Colusa	1600	Apr. 18	Aug. 24	Sept. 27	Oct. 7	35	154
Midseason group—							
Butte	1564	...do.....	Sept. 1	Oct. 4	Oct. 12	39	161
Late group—							
Wataribune	1561	...do.....	Sept. 9	Oct. 19	Oct. 22	37	176
Omachi	1573	...do.....	Sept. 11	Oct. 20	Oct. 23	37	177
Shinriki	1642	...do.....	Sept. 15	Oct. 23	...do.....	31	180
Medium grain:							
Early group—							
Pilit	81	Apr. 20	Aug. 25	Sept. 25	Sept. 29	39	152
Late group—							
From Ceylon	1241	Apr. 19	Sept. 12	Oct. 15	Oct. 19	43	172
Do	1258	Apr. 20	Sept. 11	...do.....	Oct. 20	43	172
Long grain:							
Late group—							
Honduras	1643	Apr. 18	Sept. 18	Oct. 23	Oct. 25	43	180
Carolina White	1644	...do.....	Sept. 19	Oct. 22	Oct. 24	44	179
Carolina Gold	1645	...do.....	...do.....	Oct. 23	Oct. 25	40	180

Table 24 shows the average agronomic data for 12 varieties of rice grown at Biggs during the 8-year period from 1913 to 1920, inclusive. Except for one or two varieties, the average date of sowing was

April 18, the average date of the first irrigation was April 26, and the average date of emergence was May 14. The earliest variety, Spagnuolo (C. I. No. 1585), was ripe 135 days after the first irrigation, the average date of maturity being September 8. The latest varieties required 180 days from the first irrigation to maturity. The average ripening date of the latest varieties was October 23.

Standard, or late, Wataribune, which was grown so extensively in California from 1912 to 1917, is comparatively late. The average date of ripening for this variety was October 19, or 176 days from first irrigation to maturity.

Colusa (C. I. No. 1600) is one of the most popular early varieties grown in California. The average date of ripening of Colusa rice was September 27 and the average number of days from first irrigation to maturity 154. Colusa is 22 days earlier than standard, or late, Wataribune, and 7 days earlier than Butte. Onsen, a variety very much like Colusa, matures in about 151 days.

Butte (C. I. No. 1564) was grown quite extensively in California in 1918 and 1919. The average date of ripening for the Butte variety was October 4 and the average number of days from first irrigation to maturity 161.

VARIETIES GROWN ON SMALL INCREASE PLATS.

The yields of 28 varieties and strains of rice grown on small increase plats during the 7-year period from 1915 to 1921, inclusive, are shown in Table 25. One of the varieties listed in Table 25 is a medium-grain rice, Selection No. 133; two are long-grain rices, C. I. Nos. 461 and 1168, and the remaining 25 are short-grain rices.

The varieties and strains included in Table 25 with a few exceptions have not been grown long enough to determine their yielding capacity over a series of years. The results, however, show that the short-grain rices yield better than the medium-grain or long-grain rices in California.

Our results at Biggs indicate that unless a variety does well when first introduced it will not become acclimated and better adapted by growing it for a series of years. Selection of varieties not well adapted to our conditions has failed so far to improve them for our section. The varieties that are adapted can be improved by selection unless they are pure-line varieties.

TABLE 25.—*Annual and average yields of 28 varieties and selections of rice grown in small increase plats at the Biggs Rice Field Station, Biggs, Calif., during the 7-year period from 1915 to 1921, inclusive.*

[Sizes of plats: In 1915, 1916, and 1917, one seventy-fifth of an acre; in 1918, one sixty-fourth of an acre; in 1919 and 1920, one-sixtieth of an acre.]

Type, group, and variety.	C. I. No.	Yield per acre (pounds).										
									Average.			
		1915	1916	1917	1918	1919	1920	1921	1918 and 1919.	1918 to 1920.	1919 to 1921.	1920 and 1921.
Short grain:												
Early group—												
From Italy	1994	5,670	2,500									
Aikoku	2028		3,445	3,030								
Midseason group—												
Oiran	1562	6,860	3,550									
Sugaippon	2321				5,214	3,584			4,399			
Kokuryo-Miyako	2329						3,069	2,880				2,975
Selection No. 118							3,036	2,880				2,958
Selection No. 120							2,640	2,460				2,550
Selection No. 126							2,904	2,580				2,742
Selection No. 127					5,610	3,712	3,102		4,661	4,141		
Selection No. 134					5,676	3,136	2,970	3,000	4,406	3,921	3,035	2,985
Selection No. 138					6,072	3,264			4,668			
Selection No. 139					6,204	2,816	3,498	3,000	4,510	4,173	3,105	3,249
Selection No. 147							3,366	2,670				3,018
Selection No. 156						2,816	2,970					
Selection No. 159							3,300	2,670				2,985
Selection No. 178							3,465	3,060				3,263
Selection No. 214							3,267	3,000				3,134
Selection No. 218							3,696	3,180				3,438
Selection No. 233							3,531	3,120				3,326
Late group—												
Wataribune	1561		3,900	5,925	5,445	2,688	3,289		4,067	3,807		
Unnamed	1991	5,950	2,080	2,175								
Shiratama	2307				5,940	3,648	3,432	2,700	4,794	4,340	3,260	3,066
Omachi	2316					3,968	3,432	3,300			3,567	3,366
Unnamed	5344				5,544	2,240			3,892			
Selection No. 140						3,008	3,300					
Medium grain:												
Midseason group—												
Selection No. 133							2,310	2,130				2,220
Long grain:												
Late group—												
Asse Y-pung	461		3,210	2,325								
Unnamed	1168		2,780	2,475								

NURSERY EXPERIMENTS.

A large number of varieties of rice from various countries as well as many selections have been tested at the Biggs Rice Field Station. These varieties and selections have been grown in rod rows spaced 3 feet apart. Views of the rice nursery are shown in Figures 13 and 14. Varieties or selections that produced good yields and possessed the other necessary characteristics of a successful commercial rice were increased from the nursery to larger plats, and if the results were satisfactory on these plats they were sown on small increase fields. If their performance was satisfactory in the rod rows, on the plats, and on the small increase fields, the varieties or selections were increased for commercial use. From the several hundred varieties and selections tested during the past eight years, three have been increased for commercial use, namely, Colusa (C. I. No. 1600), Butte (C. I. No. 1564), and Caloro (C. I. No. 1561–1). It is comparatively easy to secure varieties or selections that have one or more desirable qualities, but it is difficult to find one that possesses all the desirable qualities that would make it a popular variety for growers, millers, and consumers.

From the grower's standpoint, earliness, high yield per acre, stiff straw, and freedom from shattering are the important qualifications. While freedom from shattering is essential, yet the variety must thresh readily. The miller desires a rice that mills well and is in

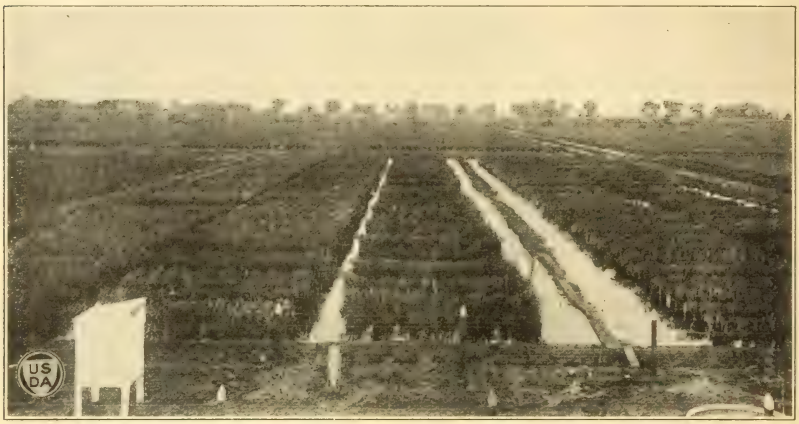

FIG. 13.—General view of the rice nursery at the Biggs Rice Field Station, with the field plats in the background.

demand on the market. Shape and size of grain, quality, and flavor are important factors with millers and consumers.

During the nine years from 1913 to 1921, inclusive, 163 varieties and selections have been grown in rod rows. The rows were 3 feet apart and the plants spaced 6 inches apart in the row. When the stand was perfect there were 33 plants in each row. Spaced plant-

FIG. 14.—Portion of the rice nursery at the Biggs Rice Field Station shortly before the crop matured.

ings have yielded less per row than bulk plantings. The annual and average yields in pounds per row of the 163 varieties and selections grown in rod rows are given in Table 26. Each row is a pure line, all the seed having come from one head. The stands were very poor in 1919. New varieties or selections were added from year to year.

TABLE 26.—*Annual and average yields of 163 varieties of rice grown in rod rows in the nursery experiments at the Biggs Rice Field Station, Biggs, Calif., during periods of varying length in the nine years from 1913 to 1921, inclusive.*

[The superior in lex figures represent the number of rows included where more than one was grown.]

Variety.	C. I. No.	Yield per rod row (pounds).									Average.		
		1913	1914	1915	1916	1917	1918	1919	1920	1921	5 years, 1917 to 1921.	6 years, 1916 to 1921.	9 years, 1913 to 1921.
Unnamed	5	1.17[2]	1.87[2]	3.00	1.00	0.12[a]	1.50	0.25	2.00	0.25	0.82	0.85	1.24
Binabagitango	482	2.20[2]	1.50	2.00[2]	1.00	2.44	2.00	.75	1.00	1.00	1.44	1.37	1.54
Unnamed	1164	1.82[2]	1.62[2]	2.00	1.75	2.12	2.25	1.00	1.50	.75	1.52	1.56	1.65
Do	1168	1.60[2]	1.30[2]	2.37	1.50	1.80	1.50	1.00	1.25	1.20	1.35	1.38	1.50
Do	1240	2.25[2]	1.50	2.12	.87	2.80	2.12	2.00	1.50	.25	1.73	1.59	1.71
Do	1241	1.20[2]	3.00[2]	2.81[2]	1.33[3]	2.12[3]	1.92[3]	1.50[3]	1.08[3]	.25[3]	1.37	1.37	1.69
Do	1244	3.72[2]	1.75	2.25	2.59	3.93	2.00	1.00	1.25	.40	1.72	1.85	2.00
Do	1288	2.40[2]	2.60	2.25	2.00	1.80	2.25	1.25	2.25	.25	1.56	1.63	1.89
Makuno Uchi	1308	3.82[2]	3.00[2]	3.25	3.12	3.50	2.25	1.25	1.50	.50	1.80	2.02	2.47
Pakhasali Bhadai	1316	1.57[2]	2.75	2.87	1.25	1.00	1.00	.75	1.75	.40	.98	1.03	1.48
Laer Chap	1322	2.82[2]	3.12[2]	2.87	1.55[2]	2.68	2.00	1.00	1.50	.50	1.54	1.54	2.00
Chieng Yu	1323	2.02[2]	2.75	2.12	1.00	2.18	2.25	1.50	1.25	1.00	1.64	1.53	1.79
Sam Sai	1331	2.27[2]	3.10	2.87	2.00	2.56	2.75	1.75	1.75	1.75	2.11	2.09	2.31
Nun Key	1334	2.67[2]	4.15	3.12	2.25	2.00	2.00	1.50	2.25	1.50	1.85	1.92	2.38
Jippon Tsu	1338	3.32[2]	3.75	2.50	2.59	2.44	1.62	1.25	1.50	1.25	1.61	1.76	2.24
Unnamed	1428	3.37[2]	1.60[2]	3.12[2]	2.87	4.12	2.00	2.00	1.75	1.75	2.32	2.42	2.51
Nugengwa	1436	1.97[2]	2.87[2]	2.12	2.00	2.06	2.12	1.25	1.75	1.50	1.74	1.78	1.96
Unnamed	1465	4.40[2]	3.00	2.75	3.25	4.36	2.25	2.00	1.50	1.75	2.37	2.52	2.81
Wanica	1496	2.87[2]	1.25	2.00[2]	1.25	3.06	1.25	.50	1.00	1.00	1.36	1.34	1.58
Unnamed	1577	3.35[2]	2.50	2.50	1.00	4.18	2.50	2.25	1.50	1.50	2.39	2.16	2.39
Zo tsen how sung	1711	2.20	2.00	1.50	2.00	2.50	1.50	1.00	1.50	1.00	1.50	1.58	1.69
Wataribune	1531	4.42[2]	3.25[2]	3.12	3.37[2]	5.58[3]	2.25[3]	2.00[3]	1.80[3]	2.25	2.69	2.88	3.12
Asse Y-pung	461	.....	1.00	2.50	1.25	2.74	1.75	.50	.75	1.00	1.35	1.33	.....
Unnamed	1167	.....	2.60	2.87	1.00	1.87	2.00	1.25	.75	1.25	1.42	1.35	.....
Do	1258	.....	2.60	3.00	2.18[2]	2.09[2]	2.25[3]	.75[3]	1.42[3]	.87	1.88	1.81	.....
Oiran	1562	.....	3.75	4.00[3]	3.00[2]	2.31	1.50	2.00	1.50	1.50	1.76	1.97	.....
Unnamed	1991	.....	1.57[3]	3.50	2.06[3]	1.50	1.75	.25	1.00	1.00	1.10	1.26	.....
Do	1992	.....	2.42[3]	3.50	2.87	3.00	1.50[2]	1.12[2]	1.12[2]	.50[2]	1.45	1.69	.....
Do	1994	.....	2.42[2]	2.36[3]	1.50	2.06	1.44[2]	1.12[2]	1.25[2]	.50[2]	1.27	1.31	.....
Do	1995	.....	2.37[2]	3.05[2]	1.87	1.62	1.12[2]	.87[2]	1.62[2]	.25[2]	1.10	1.29	.....
Do	1247	.....	.....	2.00	1.00	2.06	1.87	1.00	1.50	.25	1.34	1.28	.....
Do	1546	.....	.....	2.87	1.25	3.36	2.00	2.00	1.75	1.25	2.07	1.94	.....
Do	1551-1-A	.....	.....	1.25	1.75	.93	.87	1.00	1.00	.50	.86	1.01	.....
Butte	1554	.....	.....	3.94[2]	3.25	3.53[2]	1.25[3]	2.25[3]	1.67[3]	1.33[3]	2.01	2.21	.....
Spagnuolo	1585	.....	.....	2.37	2.00	1.21[2]	1.20	2.25	1.75	1.00	1.48	1.57	.....
Unnamed	1585–3	.....	.....	2.00	1.75	1.50	1.00	2.12[2]	2.00	1.00	1.52	1.56	.....
Do	1598–4	.....	.....	2.12	2.00	1.25	1.12	2.25	2.00	1.00	1.52	1.60	.....
Colusa	c 1600	.....	.....	3.37	2.87	4.03[2]	.56[4]	2.25[4]	2.12[4]	1.58[4]	2.11	2.24	.....
Shinriki	1642	.....	.....	3.81[2]	3.87	5.06	1.62[2]	2.62[2]	2.50	1.12[2]	2.58	2.80	.....
Unnamed	1694	.....	.....	2.00	1.12	2.00	.50	0	.50	0	.00	.09	.....
Do	1913	.....	.....	2.37	1.12	2.36	1.25	1.50	1.25	1.00	1.47	1.41	.....
Do	1917	.....	.....	2.75	2.25	2.50	1.50	.50	1.75	.75	1.40	1.54	.....
Do	1925	.....	.....	2.62	4.00	2.80	0	3.00	3.00	2.00	2.16	2.47	.....
Do	b 1996	.....	.....	2.31[2]	1.00	1.06	.75	.75	1.00	.25	.76	.80	.....
Honduras	1642	.....	.....	.....	1.75	4.25	1.12[2]	.75[2]	2.12[2]	.62[2]	1.77	1.77	.....
Carolina White	1644	.....	.....	.....	1.50	4.06	2.00	.25	2.50	.87[2]	1.94	1.86	.....
Carolina Gold	1645	.....	.....	.....	1.12	2.62	1.00	.50	2.25	1.00	1.47	1.42	.....
Swamp	2008	.....	.....	.....	2.87	2.00	1.50[2]	1.25[2]	1.62[2]	.50[2]	1.37	1.62	.....
Takenari	2029	.....	.....	.....	1.25	2.80	1.75[2]	1.37[2]	1.50[2]	.75[2]	1.63	1.57	.....
Kamenoo	2031	.....	.....	.....	1.75[2]	2.34[2]	.75	1.00	1.25	b .25	1.12	1.22	.....
Sheketori	2033	.....	.....	.....	2.12[2]	2.21[2]	1.75[2]	1.12[2]	1.25[2]	.75[2]	1.42	1.55	.....
Benlloch	2051	.....	.....	.....	2.06[2]	2.62	1.42[2]	.62[2]	1.37[2]	.50[2]	1.31	1.43	.....
Do	2052	.....	.....	.....	2.25	2.68	1.62[2]	1.25[2]	1.50[2]	.75[2]	1.56	1.68	.....
Do	2058	.....	.....	.....	2.25[2]	2.56	1.50	1.17[2]	1.50[2]	1.00[2]	1.55	1.60	.....
Amonquili	2084	.....	.....	.....	1.12	1.93	1.12	.75	1.25	.50	1.11	1.11	.....
Bomba	2085	.....	.....	.....	2.06	2.15[2]	2.00	1.12[2]	1.75[2]	1.25[2]	1.65	1.72	.....
Aitoku	2290	.....	.....	.....	1.62	2.25	2.25	1.00	2.00	1.75	1.85	1.81	.....
Unnamed	2291	.....	.....	.....	2.12	3.62	1.75	1.50	2.00	1.50	2.07	2.08	.....
Geppu	2292	.....	.....	.....	1.00	1.00	1.62	1.25	1.25	.75	1.17	1.13	.....
Fukuyama	2293	.....	.....	.....	3.00	4.50	2.12[2]	2.62[2]	2.00[2]	1.75[2]	2.60	2.67	.....
Unnamed	2294	.....	.....	.....	3.00	3.87	3.25	3.00	2.50	1.50	2.82	2.85	.....
Takenari	2295	.....	.....	.....	3.00	4.50	2.25	2.00	2.00	1.50	2.45	2.54	.....
Aikoku	2297	.....	.....	.....	2.00	2.25	1.50	1.50	1.50	.50	1.45	1.54	.....
Unnamed	2298	.....	.....	.....	1.87	2.00	1.75	2.00	2.00	1.00	1.75	1.77	.....
Kinko	2299	.....	.....	.....	2.12	1.50	1.25	2.00	1.50	b .50	1.35	1.48	.....
Shinriki	2300	.....	.....	.....	2.12	4.87	3.25	2.25	2.00	2.00	2.87	2.75	.....

[a] Yield in 1918 damaged by cow.

[b] Yield reduced by birds about 50 per cent.

TABLE 26.—*Annual and average yields of 163 varieties of rice grown in rod rows in the nursery experiments at the Biggs Rice Field Station, Biggs, Calif., during periods of varying length in the nine years from 1913 to 1921, inclusive*—Continued.

Variety.	C. I. No.	Yield per rod row (pounds).									Average.		
		1913	1914	1915	1916	1917	1918	1919	1920	1921	5 years, 1917 to 1921.	6 years, 1916 to 1921.	9 years, 1913 to 1921.
Takenari	2301				2.75	4.25	2.25	2.00	2.00	1.50	2.40	2.46	
Kinko	2302				1.00	2.25	1.62	1.60	1.50	.75	1.54	1.45	
Miyako	2303				2.25	4.74	1.75	2.50	2.75	1.50	2.65	2.58	
Tshijiro	2304				2.25	3.12	1.25	1.75	2.00	1.00	1.82	1.90	
Shinshu-Kinko	2305				1.62	1.36	1.50	.75	1.50	.40	1.10	1.19	
Aikoku	2306				2.25	3.36	1.62	1.50	2.00	1.00	1.90	1.96	
Shiratama	2307				2.50	4.68	2.50	1.75	2.50	1.30	2.55	2.54	
Unnamed	2308				2.25	1.25	1.50	1.25	2.00	1.00	1.40	1.54	
Do	2309				1.12	1.18	1.00	1.00	1.25	b.40	.97	.99	
Do	2310				2.00	2.00	1.20	.75	1.50	b.50	1.19	1.33	
Geppu	2311				.87	1.87	1.50	1.00	1.50	b.60	1.29	1.22	
Araki	2312				2.25	3.31	1.50	1.25	1.50	1.00	1.71	1.80	
Geppu	2313				1.25	3.31	1.50	.75	1.50	b.25	1.46	1.43	
Goka-Wase	2315				2.12	4.36	2.25	1.50	2.25	1.75	2.42	2.37	
Shinriki	2319				2.25	4.62	1.75	1.75	2.25	2.00	2.47	2.44	
Bujen-ho	2322				2.50	4.62	2.33[3]	2.00[3]	2.58[3]	1.33[3]	2.57	2.56	
Tama-Nishiki	2323				2.50	4.31	1.25	2.00	2.00	1.50	2.21	2.26	
Geppu	2324				2.25	2.00	0	1.25	1.50	1.00	1.15	1.33	
Kibi	2326				2.00	4.93	2.25	1.75	1.50	2.25	2.54	2.45	
Unnamed	2328				2.25	2.62	1.62	.75	1.50	.50	1.40	1.54	
Kokuryo-Miyako	2329				2.50	3.25	2.00[2]	2.00[2]	1.00[2]	.87[2]	1.82	1.94	
Gungeki	2331				2.50	3.44	2.05[3]	1.67[3]	2.00[3]	.92[3]	2.02	2.10	
Tse-Nishiki	2332				4.00	3.93	2.87[2]	1.75[2]	2.25[2]	1.00[2]	2.36	2.63	
Geppu	2333				1.75	1.50	1.12	1.00	1.25	b.25	1.02	1.15	
Kameno-o	2334				2.25	2.62	1.25	.75	1.50	b.25	1.27	1.44	
Kokuryo-Miyako	2335				3.25	3.12	1.75[2]	2.00[2]	1.50[2]	.75[2]	1.82	2.06	
Araki	2336				3.50	3.56	1.50	2.25	1.50	.75	1.91	2.18	
Unnamed	2337				3.75	3.87	2.50	2.25	2.25	1.25	2.42	2.65	
Takenari	2338				4.25	3.50	2.50	2.25	2.00	1.00	2.25	2.58	
Usa-Nishiki	2339				3.00	2.00	3.00	2.75	2.00	1.50	2.25	2.38	
Geppu	2340				1.50	1.93[2]	1.06	1.50	1.50	b.25	1.25	1.29	
Uhel	2341				1.50	2.12	1.75	2.00	1.75	.75	1.67	1.65	
Sekitori	2342				3.25	2.87	2.12	2.00	1.75	1.00	1.95	2.17	
Unnamed	2343				1.50	2.25	2.00	1.75	2.00	1.00	1.80	1.75	
Kinko	2344				2.50	2.68	1.12	1.25	1.00	b.50	1.31	1.51	
Do	2345				2.75	2.12	1.12	1.25	1.25	b.50	1.25	1.50	
Wase-Shinriki	2346				3.00	3.50	2.25	2.25	2.25	1.50	2.35	2.46	
Kinko	2347				1.85	1.50	.75	1.30	1.50	.50	1.11	1.23	
Samba	2348				3.60	3.93	2.87[2]	2.50[2]	2.25[2]	1.12[2]	2.53	2.71	
Geppu	2353				2.10	1.00	1.00	1.50	1.50	b.50	1.10	1.27	
Unnamed	2354				2.75	1.68	1.37	1.50	1.25	b.60	1.28	1.53	
Yamadako	2357				1.50	5.00	2.25	2.50	1.75	1.50	2.60	2.42	
Unnamed	2358				2.25	2.50	1.37	1.50	1.25	.50	1.42	1.56	
Do	2359				2.25	5.06	2.50	2.25	2.25	1.75	2.76	2.68	
Do	2360				1.10	4.50	2.50	2.75	2.25	1.50	2.70	2.43	
Aikoku	2361				2.75	1.50	1.50	2.00	1.50	1.00	1.50	1.71	
Wataribune	1561				3.50	5.00[2]	2.81[5]	2.75[5]	1.85[5]	2.25	2.93	3.03	
Unnamed	2116					2.93	2.50	2.25	1.75	2.00	2.29		
Do	2119					2.25	2.25	2.00	1.50	1.50	1.90		
Do	2120					2.00	2.25	1.75	1.25	.75	1.60		
Do	2131					3.18	2.87[2]	2.37[2]	2.00[2]	2.00[2]	2.48		
Do	2142					.93	2.00	1.50	1.25	1.00	1.34		
Do	2151					2.50	2.25	1.75	1.50	1.00	1.80		
Do	2155					1.74	2.50	2.25	1.75	2.50	2.15		
Do	2156					2.62	1.75	1.00	1.50	1.00	1.57		
Do	2165					1.56	1.87	1.25	1.50	b.75	1.39		
Omachi	2316					5.93	2.50	2.25	2.75	1.75	3.04		
Sekitori	2320					3.50	1.75	2.00	1.50	1.50	2.05		
Sugaippon	2321					4.25	1.75	1.25	2.00	1.25	2.10		
Unnamed	2349					1.00	1.25	1.50	1.50	b.25	1.10		
Do	2350					4.06	1.75	3.00	2.00	1.75	2.51		
Do	2351					3.00	1.25	2.00	2.25	1.50	2.00		
Yamato-Nishiki	2355					3.62	2.25	3.25	1.75	1.50	2.47		
Unnamed	2356					5.12	2.00	2.50	1.75	1.50	2.57		
Do	2363					1.36	1.20	1.25	1.25	b.25	1.06		
Oba	2365					1.62	1.00	2.00	1.25	b.60	1.29		
Pinolores	2863					3.44	2.75	0	.75	.25	1.44		

b Yield reduced by birds about 50 per cent.

TABLE 26.—*Annual and average yields of 163 varieties of rice grown in rod rows in the nursery experiments at the Biggs Rice Field Station, Biggs, Calif., during periods of varying length in the nine years from 1913 to 1921, inclusive*—Continued.

Variety.	C. I. No.	Yield per rod row (pounds).											
		1913	1914	1915	1916	1917	1918	1919	1920	1921	Average. 5 years, 1917 to 1921.	Average. 6 years, 1916 to 1921.	Average. 9 years, 1913 to 1921.
Malande Blanco	4195					3.00	1.75	1.00	1.00	0.75	1.50		
Buluhan Selang	4219					2.62	1.50	1.25	1.25	.50	1.42		
Dumali	4289					1.50	1.37	1.25	1.25	.50	1.17		
Unnamed	2822					2.06	2.50	.50	.50	.50	1.21		
Do	2947					2.62	2.87	1.50	1.50	.50	1.80		
Binogako	3040					2.36	3.00	1.75	1.50	.75	1.87		
Masamfeng	3415					1.25	2.00	.25	1.00	.25	.95		
Kinanda Minutlanda	3549					1.00	1.75	1.25	2.75	.50	1.45		
Unnamed	3863					3.00	1.75	1.50	1.25	.25	1.55		
Quinanda Inuac	4373					3.18	1.75	.75	1.00	.50	1.44		
Unnamed	4579					3.25	1.75	1.50	1.25	.75	1.70		
Kinabugan	4602					5.06	2.00	2.25	2.00	1.25	2.51		
Quinanda Linalloc	4950					3.74	1.75	.50	.75	.50	1.45		
Tomao	4994					2.12	1.00	1.00	1.00	0	1.02		
Unnamed	5102					3.00	1.50	1.75	1.25	1.00	1.70		
Do	2851						1.75	0	1.25				
Initlog Dalag	2913						2.00	.50	.50				
Guinosgor	3625						1.25	1.00	1.25				
Unnamed	3801						2.00	1.50	1.00				
Isonoy	3860						2.00	1.75	1.50				
Aguyor	3937						3.00	1.00	.75				
Binocane	3090						1.75	0	.25				
Sinampaga	4147						1.25	0	.25				
Quinanda Polopot	4191						1.50	0	.25				
Sinan Juan	4211						1.75	0	.50				
Nagayon	4295						1.25	0	.25				
Cutsiam Mapula	4479						1.00	.25	.25				
Kinalamba	4653						2.50	0	.25				
Unnamed	5010						.75	0	.25				
Do	5044						.75	.25	.25				
Edith	2127						2.12[4]	1.62	1.62				

Of the varieties grown during the nine years none of them has yielded more than Wataribune (C. I. No. 1561), which averaged 3.12 pounds to the row. Other high-yielding varieties were C. I. No. 1465, an upland rice obtained from South Africa but originally from Bolivia, and C. I. No. 1428, from German East Africa, with yields of 2.81 and 2.51 pounds, respectively.

Wataribune also led all varieties and strains grown from 1914 to 1921. In this 8-year period it averaged 2.95 pounds to the row, C. I. No. 1465 again ranking second with 2.61 pounds. Oiran (C. I. No. 1562), with an average yield of 2.45 pounds, ranked above C. I. No. 1428, which averaged 2.40 pounds.

In the 7-year period from 1915 to 1921, Wataribune, with an average yield of 2.91 pounds to the row, was slightly outyielded by Shinriki (C. I. No. 1642), with 2.94 pounds. Other high-yielding strains were C. I. Nos. 1465, 1428, 1925, and 1564 (Butte). C. I. Nos. 1428, 1465, and 1925 are late short-grain varieties.

Wataribune slightly surpassed Shinriki in the 6-year period from 1916 to 1921, with 2.88 pounds to 2.80 pounds for the latter. C. I.

No. 2294 also slightly outyielded Shinriki, averaging 2.85 pounds to the row. Other high-yielding strains were C. I. Nos. 1465, 2293 (Fukuyama), 2295 (Takenari), 2300 (Shinriki), 2303 (Miyako), 2332 (Tse-Nishiki), 2337, 2338 (Takenari), 2348 (Samba), and 2359.

The average yields from the rod rows for the 5-year period show Omachi (C. I. No. 2316), to be slightly in the lead, with 3.04 pounds. A strain of Wataribune (C. I. No. 1561), is second, with 2.93 pounds. Shinriki (C. I. No. 2300), averaged 2.87 pounds for this period, while 11 other varieties averaged 2.50 pounds or better. Honduras, Carolina Gold, and Carolina White, standard long-grain rices in the Southern States, averaged less than 2 pounds to the row.

Table 27 shows the annual and average yields in pounds per rod row for the 133 varieties and selections grown in bulk rows in the nursery. The bulk rows were seeded at approximately the same rate as that used on commercial fields. These rows, except new importations, are pure-line varieties or selections. The bulk rows have given better yields as a rule than the head rows, due in part to thicker seeding and better stands. Yields of the check rows of Wataribune rice are also given.

TABLE 27.—*Annual and average yields of 133 varieties and selections of rice grown in bulk rod rows in the nursery experiments at the Biggs Rice Field Station, Biggs, Calif., during periods of varying length in the six years from 1916 to 1921, inclusive.*

[The superior index figures represent the number of rod rows included where more than one was grown.]

Variety	C. I. No.	Selection No.	Yield per rod row (pounds).						Average.		
			1916	1917	1918	1919	1920	1921	4 years, 1918 to 1921.	5 years, 1917 to 1921.	6 years, 1916 to 1921.
Wataribune	1561			5.15[2]	3.12[2]	2.37[2]	1.75[2]	1.62[2]	2.22	2.80	
Unnamed		102		4.12	2.50	1.25	1.25	1.00	1.50	2.02	
		103			3.75	2.00	2.75	1.25	2.44		
		104			2.25	2.25	2.25	1.10	1.96		
		105			2.75[2]	3.12[2]	2.75[2]	1.55[2]	2.54		
		106			3.12	2.50	3.00	1.50	2.53		
		107		4.00	3.00[2]	3.00[2]	2.87[2]	1.55[2]	2.61	2.88	
		108		4.06	2.75	2.00	2.75	1.50	2.25	2.61	
		109			3.25	2.00	3.00	1.25	2.38		
		110			2.25	2.50	2.50	1.25	2.13		
		111		5.72[2]	3.00[2]	3.62[2]	3.00[2]	1.37[2]	2.75	3.34	
Wataribune	1561			6.71[2]	4.00[2]	3.12[2]	3.12[2]	1.62[2]	2.97	3.71	
Unnamed		112			2.62[3]	3.42[3]	3.08[3]	1.33[3]	2.61		
		113		3.65[16]	3.37[4]	3.62[4]	3.19[4]	1.56[4]	2.94	3.08	
		114		6.70[3]	3.20[5]	3.75[5]	3.34[5]	1.60[5]	2.97	3.72	
		115		6.75[9]	3.90[5]	3.40[5]	3.75[5]	1.72[5]	3.19	3.90	
		116		6.43[3]	3.17[3]	3.33[3]	3.50[3]	1.50[3]	2.88	3.59	
		117			3.25	3.75	2.50	1.50	2.75		
		118			3.50	4.50	2.75	1.75	3.13		
		119			2.75	3.25	2.75	2.00	2.69		
		120			2.75	3.75	2.75	2.00	2.81		
		122		5.31	2.75	3.75	2.50	2.00	2.75	3.26	
Wataribune	1561			6.11[2]	4.00[2]	3.62[2]	2.62[2]	2.37[2]	3.15	3.74	
Unnamed		123			3.00	3.75	2.50	2.25	2.88		
		124			3.00	3.50	2.25	2.00	2.69		
		125		5.31	2.75	4.25	2.00	2.00	2.75	3.26	
		126			2.75	4.00	2.25	1.75	2.69		
		127		6.09[2]	3.00[4]	3.62[4]	3.31[4]	2.00[4]	2.98	3.60	
		128			2.75	3.25	2.50	1.25	2.44		
		129			2.75	3.50	2.75	1.75	2.69		
		131		3.00	3.50	4.00	4.00	1.75	3.31	3.25	
		132			2.75	3.75	3.25	1.50	2.81		
		133			3.12	3.75	2.75	2.25	2.97		
Wataribune	1561			64.0[2]	3.12[2]	4.12[2]	2.62[2]	2.00[2]	2.97	3.65	

TABLE 27.—*Annual and average yields of 133 varieties and selections of rice grown in bulk rod rows in the nursery experiments at the Biggs Rice Field Station, Biggs, Calif., during periods of varying length in the six years from 1916 to 1921, inclusive*—Continued.

Variety	C. I. No.	Selection No.	Yield per rod row (pounds).						Average.		
			1916	1917	1918	1919	1920	1921	4 years, 1918 to 1921.	5 years, 1917 to 1921.	6 years, 1916 to 1921.
	.....	134	.....	.....	2.92 [3]	4.08 [3]	2.75 [3]	1.95 [3]	2.93	.....	.....
	.....	135	.....	.....	2.00	3.50	1.75	1.75	2.25	.....	.....
	.....	137	.....	.....	2.50	3.50	1.75	1.75	2.38	.....	.....
	.....	138	.....	.....	2.58 [3]	4.17 [3]	2.92 [3]	2.00 [3]	2.92	.....	.....
Unnamed	.....	139	.....	.....	2.83 [3]	3.83 [3]	2.83 [3]	1.75 [3]	2.81	.....	.....
	.....	140	.....	.....	3.50	3.75	3.00	2.00	3.06	.....	.....
	.....	141	.....	.....	3.00 [2]	3.50 [2]	3.00 [2]	1.62 [2]	2.78	.....	.....
	.....	142	.....	.....	2.50	4.00	3.00	2.00	2.88	.....	.....
	.....	143	.....	.....	2.50	3.75	2.50	1.50	2.56	.....	.....
	.....	144	.....	.....	1.75	1.50	1.50	1.00	1.44	.....	.....
Wataribune	1561	.....	.....	5.97 [2]	3.75 [2]	3.62 [2]	2.12 [2]	1.87 [2]	2.84	3.47	.....
	.....	145	.....	.....	2.75	3.50	2.00	2.00	2.56	.....	.....
	.....	146	.....	.....	3.00	4.50	2.50	2.00	3.00	.....	.....
	.....	147	.....	.....	3.75	4.00	3.00	2.00	3.19	.....	.....
	.....	149	.....	4.72 [3]	2.75	2.75	2.50	1.50	2.38	2.84	.....
Unnamed	.....	151	.....	6.00	2.83 [3]	3.33 [3]	2.75 [3]	1.67 [3]	2.65	3.32	.....
	.....	152	.....	.....	2.75	2.75	2.50	1.75	2.44	.....	.....
	.....	153	.....	5.87	3.00	2.75	2.50	1.75	2.50	3.17	.....
	.....	154	.....	.....	3.00	2.50	2.25	1.50	2.31	.....	.....
	.....	155	.....	5.44	3.00 [3]	2.92 [3]	3.08 [3]	1.67 [3]	2.67	3.22	.....
	.....	156	.....	.....	2.75	2.50	2.50	1.50	2.31	.....	.....
Wataribune	1561	.....	.....	6.25 [2]	3.50 [2]	3.25 [2]	2.50 [2]	1.25 [2]	2.63	3.35	.....
	.....	157	.....	.....	1.50	.75	1.50	.75	1.13	.....	.....
	.....	158	.....	4.93 [3]	2.50 [3]	2.42 [3]	2.70 [3]	1.42 [3]	2.26	2.79	.....
	.....	159	.....	.....	2.25	2.50	1.75	1.00	1.88	.....	.....
	.....	160	.....	.....	2.75	2.75	2.00	1.25	2.19	.....	.....
Unnamed	.....	161	.....	4.99 [6]	2.25	2.25	2.00	1.25	1.94	2.55	.....
	.....	162	.....	4.97 [5]	2.50	3.25	2.00	1.50	2.31	2.84	.....
	.....	163	.....	.....	3.00	2.00	1.75	1.25	2.00	.....	.....
	.....	164	.....	4.18 [2]	2.50	2.75	2.25	1.50	2.25	2.64	.....
	.....	165	.....	5.81 [5]	2.75 [5]	3.00 [3]	2.83 [3]	1.67 [3]	2.56	3.21	.....
	.....	166	.....	4.83 [5]	2.25	2.50	2.00	1.75	2.13	2.67	.....
Wataribune	1561	.....	.....	6.82 [2]	3.62 [2]	3.00 [2]	2.12 [2]	1.87 [2]	2.65	3.49	.....
	.....	167	.....	5.02 [2]	2.50	3.00	2.00	1.50	2.25	2.80	.....
	.....	168	.....	5.34 [2]	2.87 [3]	3.00 [2]	2.75	1.42 [3]	2.51	3.08	.....
	.....	169	.....	4.96 [5]	2.25	2.75	2.00	1.25	2.06	2.64	.....
	.....	170	.....	6.05 [5]	2.69 [6]	3.06 [4]	3.00	1.62 [4]	2.59	3.29	.....
Unnamed	.....	171	.....	4.42 [6]	2.25	3.00	1.75	1.50	2.13	2.58	.....
	.....	172	.....	5.68 [3]	2.75	2.75	2.25	2.25	2.50	3.14	.....
	.....	173	.....	.....	2.00	2.75	2.00	2.00	2.19	.....	.....
	.....	174	.....	6.15 [2]	2.50 [3]	3.50 [3]	2.58 [3]	1.83 [3]	2.60	3.31	.....
	.....	175	.....	5.60 [6]	2.75 [6]	3.20	2.90 [5]	2.05 [5]	2.73	3.30	.....
	.....	177	.....	.....	2.00	2.75	2.50	2.00	2.31	.....	.....
Wataribune	1561	.....	.....	5.31 [2]	3.25 [2]	3.12 [2]	2.25 [2]	2.37 [2]	2.75	3.26	.....
	.....	178	.....	4.59 [2]	2.25 [3]	2.94 [4]	3.44 [4]	2.12 [4]	2.69	3.07	.....
	.....	179	.....	.....	1.75	2.00	2.00	1.75	1.88	.....	.....
	.....	180	.....	4.56 [3]	1.75	2.50	2.50	2.00	2.19	2.66	.....
	.....	181	.....	.....	2.25	2.75	2.50	2.00	2.38	.....	.....
Unnamed	.....	182	.....	.....	2.00	2.75	2.50	2.50	2.44	.....	.....
	.....	183	.....	.....	2.00	3.75	1.50	2.50	2.44	.....	.....
	.....	184	.....	.....	2.00	3.50	2.00	3.00	2.63	.....	.....
	.....	185	.....	.....	2.25	4.25	2.00	3.25	2.94	.....	.....
	.....	186	.....	.....	2.25	2.00	1.50	1.50	1.81	.....	.....
	.....	187	.....	.....	2.00	3.50	3.75	2.25	2.88	.....	.....
Wataribune	1561	.....	.....	5.83 [2]	2.67 [2]	3.12 [2]	2.12 [2]	1.87 [2]	2.45	3.12	.....
	.....	188	.....	.....	2.25	4.25	3.75	2.00	3.06	.....	.....
	.....	189	.....	.....	2.75	4.00	3.50	2.25	3.12	.....	.....
	.....	190	.....	.....	3.00	4.00	2.75	1.75	2.88	.....	.....
	.....	191	.....	.....	2.00	3.50	2.00	1.50	2.25	.....	.....
Unnamed	.....	192	.....	.....	2.25	3.75	2.25	1.75	2.50	.....	.....
	.....	204	.....	4.26 [10]	2.50	3.50	2.50	2.00	2.62	2.95	.....
	.....	205	.....	6.74	3.25	3.75	2.50	2.00	2.88	3.65	.....
	.....	206	.....	5.25	4.00	4.25	3.25	2.25	3.44	3.80	.....
	.....	207	.....	5.00	3.12	4.50	3.25	1.25	3.03	3.42	.....
	.....	208	.....	5.29 [11]	2.12	4.00	3.50	1.10	2.68	3.20	.....

TABLE 27.—*Annual and average yields of 133 varieties and selections of rice grown in bulk rod rows in the nursery experiments at the Biggs Rice Field Station, Biggs, Calif., during periods of varying length in the six years from 1916 to 1921, inclusive*—Continued.

Variety.	C. I. No.	Selection No.	Yield per rod row (pounds).						Average.		
			1916	1917	1918	1919	1920	1921	4 years, 1918 to 1921.	5 years, 1917 to 1921.	6 years, 1916 to 1921.
Wataribune	1561		2.81 [2]	6.65 [3]	3.87 [2]	4.87 [2]	3.12 [2]	1.75 [2]	3.40	4.05	3.85
Unnamed		209	2.00	5.53 [11]	2.50	4.00	3.00	1.25	2.69	3.26	3.05
		210	1.75	5.78 [2]	2.00	3.25	2.50	1.50	2.31	3.01	2.80
		211	2.00	5.50	2.50	4.00	2.75	1.75	2.75	3.30	3.08
		212	2.37	5.34 [2]	2.75	4.75	3.75	1.50	3.19	3.62	3.41
		213	3.12	5.22 [2]	3.00	4.50	3.50	1.25	3.06	3.49	3.43
		214	3.00	4.31	2.00	3.75	3.75	1.60	2.78	3.08	3.07
		216	3.12	5.31	3.50	4.00	3.75	2.00	3.31	3.71	3.61
		217	2.00	5.58 [5]	2.75	4.50	3.50	2.00	3.19	3.67	3.39
		218	3.00	4.62	2.75	3.75	3.25	1.25	2.75	3.12	3.10
		219	2.50	5.12	3.00	4.75	3.25	1.75	3.19	3.57	3.40
Wataribune	1561		3.50	5.18	3.62	4.87	3.00	1.75	3.31	3.68	3.65
Unnamed		221	3.00	5.07 [5]	3.00	4.75	3.25	2.00	3.25	3.61	3.51
		222	3.12	3.87	2.50	5.25	2.75	2.00	3.13	3.27	3.25
		233	3.00	4.54 [2]	3.00	4.75	3.00	2.25	3.25	3.51	3.42
Unnamed	1992			3.06	2.75	2.00	2.25	1.00	2.00	2.21	
Do	2008			2.59	2.92 [2]	3.33 [2]	2.75	.75	2.44	2.47	
Do	2030			5.99 [3]	4.31 [3]	3.75 [3]	3.25	2.02 [2]	3.33	3.86	
Do	2033			4.79 [2]	3.25	3.00	1.62	1.00	2.22	2.73	
Benlloch	2051			2.50	3.00 [2]	3.33 [2]	2.00	.50	2.21	2.27	
Do	2052			2.52	3.00	3.50	2.50	.50	2.38	2.40	
Unnamed	2054				2.25	3.00	2.75	1.50	2.38		
Wataribune	1561			6.25	3.75	4.50	2.12	1.50	2.97	3.62	
Fukuyama	2293			5.85 [5]	3.85 [5]	3.20 [4]	2.25	1.25	2.64	3.28	
Unnamed	2294				4.75	3.50	2.50	1.50	3.06		
Takenari	2295			6.31	4.08 [2]	3.42 [2]	3.00	1.67	3.04	3.70	
Shinriki	2300			6.25	4.87	3.35	2.00	1.50	2.93	3.59	
Tshijiro	2304				3.50	2.50	2.00	1.30	2.33		
Shiratama	2307			5.25	4.00	3.50	2.00	1.75	2.81	3.30	
Goka-Wase	2315				3.75	3.50	2.50	1.50	2.81		
Omachi	2316				4.25	4.00	3.00	2.00	3.31		
Shinriki	2319				4.00	3.50	2.75	2.25	3.13		
Sekitori	2320				3.37	3.12	2.50	1.75	2.69		
Wataribune	1561			5.90 [2]	4.25 [2]	3.87 [2]	2.00 [2]	1.50 [2]	2.91	3.50	
Sugaippon	2321				3.25	3.25	2.50	1.50	2.63		
Unnamed	2328				3.00	3.00	2.50	1.25	2.44		
Kokuryo-Miyako	2329			4.70 [9]	3.25 [6]	3.37 [4]	2.50	1.50	2.66	3.06	
Gunyeki	2331				3.00	3.25	2.25	1.50	2.50		
Tse-Nishiki	2332			5.60	3.50	3.00	2.50	1.75	2.69	3.27	
Kokuryo-Miyako	2335			4.62	3.00	2.75	2.25	1.50	2.38	2.82	
Samba	2348			4.00	4.00	3.25	2.75	1.50	2.88		
Unnamed	4219				3.25	1.75	2.00	1.00	2.00		
Edith	2127				3.37 [2]	1.83 [3]	2.00	2.25	2.36		
Hayashinriki				4.28 [19]	3.12 [3]	2.12 [2]	2.25 [2]	1.42 [2]	2.23	2.64	
Sue Hero				4.00	2.10 [6]	2.12 [6]	2.00 [2]	[a].50	1.68	2.14	
Hindo-dee				3.50 [19]	2.71 [5]	3.31 [4]	1.50	[a].50	2.01	2.30	
Kameno-o				2.58 [16]	2.03 [5]	1.37 [4]	1.75	[a].25	1.35	1.60	

[a] Yield reduced about 75 per cent by birds.

Most of the varieties and strains which have been grown in bulk rod rows are pure-line selections. Every eleventh row in this nursery was sown to Wataribune rice (C. I. No. 1561) as a check. Of the few selections grown for six years, none outyielded the check, two rows of which averaged 3.65 and 3.85 pounds. The highest yielding selection was No. 216, with 3.61 pounds.

A large number of varieties and pure lines were grown during the five years from 1917 to 1921. Only two of these, Selection No. 115, with a yield of 3.90 pounds, and C. I. No. 2030 (Omachi) outyielded the nearest check rows of Wataribune.

Of the 133 varieties and selections grown during the four years from 1918 to 1921 a considerable number slightly exceeded the average of the two nearest check rows in yield. Among the best of these were Selection Nos. 115, 118, 131, 134, 138, 146, 147, 175, 185, 187, 206, 216, and 233 and C. I. Nos. 2030, 2294, 2295 (Takenari), and 2316 (Omachi). Although several strains produced as high an average yield, 3.31 pounds, no other exceeded the average of the two nearest checks by as large a figure as Omachi. In all cases the varieties that have equaled or exceeded Wataribune in yield are nearly as late as or later than Wataribune. Earliness and high yield are not commonly found in the same variety, especially when grown on old rice land.

LEADING VARIETIES OF RICE FOR CALIFORNIA.

Superior yielding and milling rices may be obtained in three distinct ways. These are (1) by introducing new varieties from other rice-growing States or countries, (2) by selecting superior strains from established varieties, and (3) by breeding or hybridization. The third method is expensive and requires several years to determine the relative merits of the various forms produced.

At the Biggs Rice Field Station the first and second methods of improvement have been followed. Varieties have been introduced from practically all the rice-producing countries of the world, and many selections have been made since the station was first established. Determination of the value of these varieties and selections has constituted a large part of the work of the station, as reported in detail in the preceding pages.

The station has attempted to obtain by introduction and selection a variety or varieties that would yield well, mill well, and mature from 10 days to two weeks earlier than the standard, or late, Wataribune variety, which was sown very extensively in California from 1912 to 1917. Wataribune yields and mills well, but it matures late, and there is danger of loss of or damage to the crop in years when the fall rains begin early. For this reason early-maturing varieties that yield and mill well have been constantly in demand, because such varieties, if found, reduce the chances of loss or damage to the rice crop due to early fall rains.

The principal rice varieties now grown in California are briefly described in the following pages.

EARLY WATARIBUNE.

Early Wataribune was introduced from Japan by W. K. Brown, manager of the Moulton ranch, in 1913, when a lot of 800 pounds was imported and sown on 10 acres. This introduction was a mixture of several varieties; some were early, others late. About 90 per cent of it, however, was from 4 to 10 days earlier than standard, or late, Wataribune. It was introduced under the name of Wataribune, but because of its earlier maturity it has been known locally as Early Wataribune, or "10-day Wataribune."

Early Wataribune is a short-grain rice which yields well on new or old rice land. It matures about one week earlier, but usually yields slightly less than standard, or late, Wataribune. This rice does not lodge or shatter badly and mills well. Early Wataribune is

now the leading variety grown in California. It has, to a large extent, replaced standard, or late, Wataribune and Butte.

COLUSA.

Colusa (C. I. No. 1600) is an early short-grain rice, developed from a pure-line selection made in 1911 at the Rice Experiment Station, Crowley, La., by Charles E. Chambliss and J. Mitchell Jenkins from a Chinese variety obtained from Italy in 1909 through Dr. Haven Metcalf. This selection was grown in the nursery at the Biggs Rice Field Station in 1913, where it was later increased for distribution. In 1917 Colusa was increased commercially on about 200 acres. This variety matures about three weeks earlier than standard, or late, Wataribune. It yields and mills well. The Colusa variety is best adapted to rich new land, but does not tiller or yield well on old rice land unless it is very rich. If left standing in the field until overripe it shatters quite badly, and on extremely rich land it is inclined to lodge. Large acreages of Colusa rice were sown in 1918, 1919, and 1920. It has been and is one of the most popular early varieties grown on the new rice lands in California. This variety was first distributed as No. 1600, but was named Colusa in 1920,[7] the name of one of the principal rice-producing counties in the State.

ONSEN.

Onsen is an early-maturing short-grain rice introduced by a Japanese at Biggs in 1918. Onsen is very much like Colusa, though it matures about three days earlier and lodges more on new land. In milling quality the two varieties are similar. Onsen is not as uniform as Colusa, due largely to mixtures. Quite a large acreage of Onsen rice was sown in California in 1920 and 1921. Onsen and Colusa are so nearly alike that there are no logical reasons why both varieties should be grown in California. Colusa is generally to be preferred, because it stands up better and is more uniform in ripening than Onsen. On certain soil types, however, Onsen apparently does better than Colusa (C. I. No. 1600).

CALORO.

Several selections from the first crop of Early Wataribune which was grown on the Moulton ranch, near Colusa, in 1913, were made by E. L. Adams while in charge of the Biggs Rice Field Station. These have been tested at the station and four of the best strains were sown in 1919 on a small commercial acreage. The four selections known as Selection Nos. 1561–1, 1561–2, 1561–3, and 1561–4 were sown on 39.41 acres in 1919. The yields ranged from 6,711 to 7,874 pounds per acre. The average yield of the four selections was 7,345 pounds per acre. Selection No. 1561–1, now named Caloro, which appears to be the best, was increased again in 1920, and about 6,000 pounds were distributed in the spring of 1921. The name is made up of the first three letters of the State name, California, and the Latin word oro, meaning gold. This is the first pure-line variety of rice selected in California especially for California conditions which has proved of

[7] Chambliss, Charles E. Rice growing in California. U. S. Dept. Agr., Farmers' Bul. 1141, 22 p., 10 fig. 1920.

sufficient value to be named and distributed. Caloro should become a valuable commercial variety in California. The 1921 reports on this variety in commercial fields were favorable. Caloro matures about 10 days earlier than late Wataribune and about two weeks later than Colusa on old land.

WATARIBUNE.

Late Wataribune (C. I. No. 1561) was brought to California by the Bureau of Plant Industry, United States Department of Agriculture, in 1909, when Charles E. Chambliss conducted the first varietal experiments with rice in the State. Wataribune rice was first grown in the United States in 1908 on the farm of S. Sabaira, a Japanese, at Webster, Tex.[8] The only objection to this variety is that it matures late in the season. In yield and quality it is probably the best variety that has been grown commercially in California. It was the leading commercial variety until 1917, but has since been almost entirely

FIG. 15.—Plat of nearly mature Wataribune rice at the Biggs Rice Field Station, with part of the station buildings in the background.

replaced by Early Wataribune, Colusa, Onsen, and Caloro, varieties which mature earlier. In the varietal experiments at Biggs for the nine-year period from 1913 to 1921 the late Wataribune was the highest yielding variety. A field of this variety on the Biggs Rice Field Station is shown in Figure 15. It tillers and yields well on either old or new rice land. It is late in maturing on new land, but is considerably earlier on old land.

LESS IMPORTANT VARIETIES.

Several additional varieties of rice are being grown on small acreages in California. Some of these were formerly popular, but have now been largely replaced by newer and better varieties. Others

[8] Chambliss, Charles E., and Jenkins, J. Mitchell. Some new varieties of rice. U. S. Dept. Agr. Bul. 1127, 18 p., 4 pl., 3 fig. 1923.

have been introduced only recently or for one reason or another are less valuable than those previously discussed. These less important varieties are mentioned in the paragraphs which follow.

SUE HERO.

In 1917 Suey Hero, a Japanese at Biggs, introduced an early-maturing short-grain variety of rice from Japan. He obtained enough seed to sow 160 acres. This variety matured on September 15 and yielded well. In 1918 about 7,500 acres were sown to this variety, which was known locally as Sue Hero, but it did not meet with general approval, so the acreage sown to it has decreased in California.

Sue Hero matures early, but it does not yield well on old land, and on rich first-year land it lodges badly. These two faults combined with the undesirable characteristic of being hard to thresh have kept Sue Hero from becoming a more important commercial variety in California. Only a small acreage is sown to Sue Hero at present.

BUTTE.

Butte rice was developed from a pure-line selection made at the Rice Experiment Station, Crowley, La., by Charles E. Chambliss and J. Mitchell Jenkins in 1911 from a variety called Tokyo, which was imported from Japan in 1908 by a rice-milling company at Beaumont, Tex. It was first sown in the nursery at the Biggs Rice Field Station in 1914. It was increased in 1915, and in 1916 was sown on about 200 acres, in cooperation with farmers. In 1917 about 8,000 acres were sown to it, the allotment and sale being controlled by the Sacramento Valley Grain Association in cooperation with the Biggs Rice Field Station. The commercial yields from this variety were satisfactory. The Butte variety yields and mills well and is from 10 days to 2 weeks earlier than standard, or late, Wataribune. Like Colusa, it was named in 1920 for one of the California rice-growing counties.

Butte rice makes a rapid growth during the first two months, a distinct advantage when sown on foul land. It does not shatter nor is it eaten by ducks or other birds. It does well on new or old land and was the highest yielding early variety in California until 1917. It does not tiller as much as Wataribune and for this reason should be seeded heavier. The weak points of the variety are that it is bearded and difficult to thresh and mill. Butte has been very largely replaced during the past three years by Early Wataribune and Caloro.

TOKYO.

Tokyo is a short-grain rice that matures about the same time as Early Wataribune. This variety was brought to California from Texas by a Japanese in 1915. Tokyo yields well on new land, but does not produce as much on old land as Early Wataribune. This variety has stiff, rather short straw, stools well, and has short heads. It is uniform and closely resembles Shinriki except that it matures earlier. Very little Tokyo rice was grown in California in 1920 or 1921. This variety is distinct from the one of the same name from which Butte rice was selected.

SPAGNUOLO.

Many so-called Italian rice varieties have been tested at the Biggs Rice Field Station, and some have been grown commercially. On new land these Italian rices yield fairly well but lodge and shatter quite badly. On rice stubble they do not yield well. A very small acreage was sown to these varieties in California in 1920 and 1921. These rices mature early, but owing to low yields, shattering, and lodging have never been very popular in California. Spagnuolo, one of the leading Italian varieties, was obtained from Italy in 1909 through Dr. Haven Metcalf and was among the varieties grown that year on the Crane ranch near Biggs. It has a long beard and matures in about 135 days from the first irrigation.

EARLY PROLIFIC.

Early Prolific is one of the varieties originated by Sol Wright, of Crowley, La. It is a medium-grain rice, very much like his famous Blue Rose. Early Prolific has not been extensively grown in California, though a small acreage of it is sown each year. In favorable rice years Early Prolific yields well, but in cool years and under unfavorable weather conditions it does not develop normally. It heads and ripens late, produces low yields, and the grain is of poor quality in California.

EDITH.

Edith is another variety originated by Sol Wright at Crowley, La. It is a long-grain rice, very much like Honduras in growth and appearance. In favorable rice years Edith has produced good yields in California, but under unfavorable conditions it does not develop normally. It heads and matures late and produces rice of inferior quality. Only a very small acreage of this variety is sown in California.

CONTROL OF WEEDS.

The California rice industry has been remarkably free from insects that affect the growing crop, but since its beginning has been confronted with serious weed pests. In rice fields conditions are ideal for the growth and development of plants that inhabit wet places. These plants, being vigorous and hardy, reproduce rapidly and if not promptly controlled spread very quickly. Weeds in rice fields increase the cost of production, decrease yields, and reduce the market value of the crop. Every effort should be made to keep weeds under control by preventing them from maturing seed either in the fields or along the fences, roads, and ditches.

The worst weeds in the California rice fields are: Barnyard grass (*Echinochloa crusgalli*) and varieties, locally known as water grass; scale-grass (*Leptochloa fascicularis*), locally known as ray-grass; cattails (*Typha latifolia*), commonly called tules; spike rush (*Eleocharis palustris*), locally known as wire-grass; sedges, or umbrella plants (*Cyperus erythrorhizos*, *C. vireus*, and *C. diandrus*); canary grass (*Phalaris paradoxa*); crabgrass (*Syntherisma sanguinalis*); joint-grass (*Paspalum distichum*); red-stem (*Ammannia coccinea*); red rice (*Oryza rufipogon*); and cheat (*Bromus secalinus*).

The California rice industry has grown very rapidly, the acreage increasing from 1,400 in 1912 to 162,000 in 1920. New rice land has been plentiful and most of the growers have been short-lease tenants. The yields on first-year land are much higher than on old land. An abundance of new land which produces high yields has induced tenant growers to farm carelessly, as they could move to new tracts when the land they were farming was fouled. Careless tenants have in this way fouled thousands of acres of rice land in California.

WATER GRASS OR BARNYARD GRASS.

Barnyard grass (*Echinochloa crusgalli*) and its several varieties, locally known as water grass, have made it practically impossible to produce profitably on the same land more than three successive rice crops in California. Thousands of acres have been rendered unfit for rice culture during the past six years by this grass. When labor was cheap it was possible and practicable to keep barnyard grass under control by hand pulling, but with high-priced labor and decreased efficiency combined with an increase in barnyard grass it has not been profitable to keep it under control by this method for more than three or four years in succession on the same land.

There are several different varieties of barnyard grass, some of which mature early and others late. The range of maturity is from June 25 to October 20. Early red barnyard grass is a native of California and was present along the streams and in irrigated sections before rice growing began. This variety matures early. Other varieties have apparently been introduced with rice seed from other rice-growing countries, and these range in maturity from July 20 to October 20.

Barnyard grass has been permitted to grow along the canal banks of the irrigation systems and the matured seed has been carried by the irrigation water to the rice fields. Winter floods, careless threshing outfits, unclean seed rice, and birds are all agencies that have assisted in the distribution of barnyard grass in the California rice fields. Several methods of control have been tried, with varying degrees of success.

HAND PULLING.

When the rice industry was young and barnyard grass was not so abundant as it is at present, it was possible to keep this weed under control by persistent hand pulling. Barnyard grass, like rice, requires high temperature and moisture to insure good germination. Therefore, the rice and grass usually germinate and start growth at the same time. The grass, however, after two weeks grows faster than the rice, and by June it is usually taller. Some varieties of water grass can be distinguished from rice by their dark purplish color, but the so-called white water grass is a much lighter green than most varieties of rice.

If water grass is to be controlled by pulling, the plants should be removed from the rice fields before they mature seed. Pulling should begin about June 25 and continue until the rice crop is mature. It is necessary to pull the plants from each field at 10-day intervals.

CULTIVATION.

Barnyard grass can be materially reduced on foul land by thorough cultivation. The best method of control consists of fallowing the land. In the spring the foul fields should be irrigated to insure germination of the weed seed. Then, before the land gets too dry and before any of the grass matures seed, the land should be plowed shallow. In July another irrigation should be given, and if a second growth of grass appears the land should be plowed shallow again. This treatment will kill most of the young grass plants, but this method is considered too expensive for general use. In the fall the land can be sown to some grain crop, such as wheat or barley. After harvesting a grain crop, the land can be sown to rice the following spring, and good yields should be obtained.

IRRIGATION.

Many attempts have been made to control or eradicate barnyard grass by changing the usual method of irrigation. The writer has observed several fields submerged at various times and at various depths during the past three years.[9] The following effects have been noted: Early applications of water and continuous submergence prevent to a large extent the growth of early red barnyard grass. When the land is submerged 6 inches deep early in the season, poor stands of rice are sometimes obtained. Deep continuous submergence after the rice and weeds have emerged will suffocate most of the red barnyard grass, but the rice will stretch through the water and continue to grow. Deep continuous submergence if started too late in the spring may result in poor stands, due apparently to the scalding of the young rice sprouts and the formation of a scum on the water which prevents the emergence of the rice.

If the land is to be submerged continuously after seeding, the rice should be sown broadcast on the surface at the rate of 150 pounds per acre, but if submergence is to be delayed until the rice and barnyard grass have emerged, then the seed can be drilled or sown broadcast in the usual way. Some growers submerge the fields, let the water get warm, and then broadcast the rice in the water. Good stands are usually obtained in this way, and less seed is required because no rice is covered with too much soil, but the method has some drawbacks for use on large acreages. Rice germinates in the water and makes a slender growth until it reaches the water surface. It then lies prostrate on the surface of the water for several days. At this time strong winds often damage the young rice plants by breaking them off and uprooting them. In about 10 days or 2 weeks the rice stands erect and looks normal in all respects. Rice seems to stool as well when grown in this way as it does when irrigated in the usual manner. A scum sometimes forms on the water and bakes on top before the rice emerges, preventing the growth of the rice and causing thin stands.

The successful control of barnyard grass by continuous deep submergence depends to a large extent upon the time of seeding, rate of seeding, and effective control of the depth of water. Fluctuation in

[9] Extensive experiments in the control of water grass by irrigation were conducted at Biggs in 1922 and also by the California Agricultural Experiment Station at Cortena, Colusa County, but the results of these were not available when this bulletin was written.

the depth of water produces variable results. On high ground that can not be continuously submerged there is usually a great deal of grass. On low land submerged too deeply the stand of rice is often poor, but the grass is usually killed.

Early, deep, continuous submergence of rice controls to a marked extent the early red barnyard grass, which is the most abundant variety in California, and some of the other forms, but the late white forms do not seem to be controlled by it. These late types are usually present on submerged fields without regard to the manner in which the water is handled. The grass locally known as white water grass survives under such treatment and appears to increase from year to year. The levees are always covered with a rank growth of water grass on foul fields.

Notwithstanding these difficulties, deep continuous submergence is quite effective in the control of water grasses and enables the growing of profitable crops on land which is too foul for rice production under the usual irrigation methods. On clean land it is probably best to follow the old system of irrigation, as unfavorable temperatures and deep water may cause poor stands. On the other hand, continuous submergence of clean land may prevent it from becoming foul.

During the period of high prices for rough rice it was possible and profitable in many cases to produce rice on foul land by continuous submergence, but in normal times at normal prices this method may or may not give profitable results. This matter is now under investigation. It is a rather uncertain method of production, because (1) it is impossible to maintain a uniform depth of water on each check on account of variations in the land surface, (2) water can not always be obtained from the canal when wanted and needed, (3) if submerged too early poor germination and stands are often obtained, and (4) if sown and submerged too late in the spring poor stands are often obtained. Deep continuous submergence is most effective in the control of early barnyard grass, but late-maturing water-grass types are more resistant to control by deep submergence.

EXPERIMENTS IN WATER-GRASS CONTROL.

In 1921, experiments to control water grass by irrigation were conducted at the Biggs Rice Field Station. The seed-bed preparation, method of seeding, and method of irrigation on the different plats were as follows:

On plat 1 rice was sown broadcast at the rate of 150 pounds per acre on spring-plowed rice stubble on which a reasonably good seed bed had been prepared by disking and dragging. The land was harrowed after sowing. Plat 2 was given the same seed-bed preparation as plat 1, but the rice was drilled at the rate of 150 pounds per acre. Plat 3 was prepared and seeded like plat 1, but was not harrowed after sowing. Plats 1, 2, and 3 were sown May 9 and irrigated and drained twice before holding the water continuously. The rice and barnyard grass had emerged May 30, and at the third irrigation the plats were submerged about 6 inches deep. Thereafter the water was held 6 inches deep continuously until the rice was ready to drain for harvest.

On plat 4 rice was sown broadcast at the rate of 150 pounds per acre on May 16 on spring-plowed rice stubble with a rough seed bed, then submerged 2 inches deep on May 21. The water was held at

that depth until the rice had emerged through the water; then the depth was increased to 6 inches and held continuously until the rice was ready to drain for harvest.

Plat 5 was sown broadcast at the rate of 150 pounds per acre on May 16 on spring-plowed rice stubble with the same seed-bed preparation as plat 4. After May 21 this plat was kept wet with some water standing on low spots until the rice was about 2 inches high. The water was then increased to about 6 inches and held continuously until the rice was ready to drain for harvest.

On spring-plowed rice stubble with the same seed-bed preparation as plat 4 rice was sown broadcast on plat 6 at the rate of 150 pounds per acre and the plat submerged 6 inches deep on May 21. The water was held continuously at that depth until the rice was ready to drain for harvest.

Plat 7 was spring-plowed rice stubble with the same seed-bed preparation as plat 4. This plat was submerged on May 21, and the rice was sown broadcast in the water at the rate of 150 pounds per acre on May 25. The water was held 6 inches deep continuously until the rice was ready to drain for harvest.

In 1913, 1914, and 1915 the land on which the water-grass control experiment was conducted in 1921 was part of a commercial rice field, and the last year it was very foul. In 1916 the land was fallow with cultural methods for water-grass eradication; in 1917 it was sown to grain sorghums and cultivated to kill grass. In 1918 this land was sown to rice and the water grass pulled; in 1919 it was fallow with cultural methods for water-grass eradication; and in 1920 it was sown to rice and was very foul with water grass.

The fact that the grass was pulled in 1918 and no grass was allowed to mature seed during the fallow year 1919 would lead one to expect the land to be reasonably free from grass in 1920, but instead it was very foul. There were no winter floods in 1919 to bring in a new supply of grass seed. However, during the 4-year period from 1916 to 1919 the land had been cultivated rather shallow each year to eradicate the grass, while in 1920 it was spring-plowed rather deep. This deep plowing apparently brought to the surface a new supply of grass seed that had been in the ground below the depth worked in previous fallow years, and this seed germinated with the rice when irrigated in 1920.

The yields and agronomic data on the water-grass control experiments at the Biggs Rice Field Station in 1921 are shown in Table 28.

The land on which the water-grass control experiments were conducted apparently increases in fertility from plat 1 to plat 7; therefore, the irrigation methods that were most effective in the control of the grass did not necessarily result in the highest yields per acre.

The rice on all plats had partly emerged through the water on June 13, and the elongated plants were lying on the surface. Near the levees, where the water was 8 to 10 inches deep, considerable rice was killed by the formation of a scum on the surface of the water. This scum prevents the rice from emerging through the water. A scum is usually present when crops are grown by continuous submergence and often causes poor stands on low spots where the water is 10 to 12 inches deep. On June 25 the elongated rice plants were still floating on the surface of the water, but by July 2 most of the plants were erect. The stands ranged from fair to excellent.

TABLE 28.—*Yields and agronomic notes on the water-grass control experiments with Caloro rice sown at the rate of 150 pounds per acre at the Biggs Rice Field Station, Biggs, Calif., in 1921.*

Plat.	Date.						Stand (per cent).	Height (inches).	Yield (pounds).
	Sown.	First irrigation.	Emerged.	Headed.	Ripe.	Harvested.			
No. 1	May 9	May 12	May 30	Sept. 2	Oct. 8	Oct. 11	75	30	[1] 1,658
No. 2	do	do	do	do	do	do	100	30	[2] 2,284
No. 3	do	do	do	do	do	do	95	32	3,028
No. 4	May 16	May 21	June 6	Sept. 14	Oct. 11	do	90	36	3,272
No. 5	do	do	do	do	do	do	85	36	3,168
No. 6	do	do	do	do	do	do	90	33	3,150
No. 7	May 25	do	June 10	Sept. 5	do	do	100	32	3,230

[1] Wire-grass reduced the yield.

The yields obtained ranged from 1,658 pounds on plat 1 to 3,272 pounds per acre on plat 4. Plats 1, 2, and 3 were practically free from red barnyard grass, but there were some late water grasses present. Considerable barnyard grass grew on plats 4 and 5. Plats 6 and 7 were practically free of red barnyard grass, but there were some late water grasses on these plats. Spike rush (*Eleocharis palustris*), locally known as wire-grass, was largely responsible for the low yield on plat 1.

All plats were drained from September 21 to 25. The rice obtained was of good quality, and only a very small quantity of grass seed was present in the threshed grain.

The water-grass control experiments in 1921 appear to justify the following conclusions, which may be somewhat revised on the basis of further experiments: (1) On land irrigated and drained in the usual way until the rice and water grass emerge, then submerged 6 inches deep and the water held continuously, the rice emerges through the water but the early barnyard grass is unable to emerge and is killed. (2) Rice sown broadcast and submerged 6 inches deep continuously from the first irrigation germinates and emerges to the surface of the water, but the early barnyard grass does not emerge. (3) Sowing rice in 6 inches of water resulted in a good stand of rice, but early barnyard grass was unable to emerge through the water. (4) In order to prevent early red barnyard grass from emerging it must be kept under 4 to 6 inches of water continuously. (5) It is easier to get a good stand of rice by drilling or broadcasting and irrigating in the usual way until the rice has emerged than by broadcasting and submerging the land immediately. (6) Better stands are obtained by seeding in the water than by seeding and then holding the water continuously, but seeding in the water is not practicable on a large scale. (7) Broadcasting in 6 inches of water, or broadcasting and immediately submerging in 6 inches of water and then holding this depth continuously, appear to be about equally effective in controlling water grass and more effective than drilling or broadcasting and irrigating the rice up before submerging 6 inches deep.

Rice will germinate under water, but it does not germinate well under water and soil. Therefore, if water is to be held continuously the seed bed should be compact and level so that the seed when broadcasted will remain on the surface. If rice is to be submerged

early and the water held continuously the rate of seeding should be heavier than when it is grown in the usual way.

To kill young water-grass plants they must be kept under 4 to 6 inches of water continuously. Fields, therefore, should be as level as possible, so that the water can be held at a uniform depth over the entire check.

JAPANESE OR WHITE WATER GRASS.

The late, vigorous water grass locally known as Japanese or white water grass does not appear to be materially reduced by early, deep, continuous submergence; in fact, this variety seems to increase from year to year under the continuous submergence method of irrigation. When this grass is thick it is one of the worst types in the rice fields. It has an extensive root system, stools abundantly, and where thick materially reduces the yield of rice. Good cultivation preceding fallow and dry farming help to control this grass.

SCALE-GRASS.

Scale-grass (*Leptochloa fascicularis*), locally known as ray-grass, is spreading quite rapidly in the California rice fields. This grass stools abundantly and matures from June 20 to October. The slender, weak stalk when young makes it practically impossible to pull this grass economically. Scale-grass will stretch through water just as quick as, if not quicker than, rice, so it can not be suffocated after it has started growth. When mature the seeds drop to the ground or water and are seldom, if ever, present in the threshed grain. The seeds of scale-grass are much smaller than those of rice. As they will germinate as soon as mature, the grass may be reduced by continuous submergence. The seed which falls to the water will germinate and the plants may then be destroyed by natural agencies before they reach maturity in the fall. On one plat continuously submerged last year there was considerable scale-grass, but the same plat continuously submerged this year has practically none. Improved drainage and good cultivation should aid in the control of this grass.

SPIKE RUSH.

Spike rush (*Eleocharis palustris*), locally known as wire-grass, is abundant in the shallow irrigation ditches, on levees, and particularly on the low, poorly drained rice land. It spreads by means of underground rootstocks. The spike rush usually gets started in a field near the levees or corners, where it is difficult to do a good job of plowing. It then continues to spread by means of the underground rootstocks. Rice can not grow where the spike rush is thick. Improved drainage and thorough cultivation will eradicate this weed. The spike-rush sod should be plowed with a moldboard plow, each layer of sod being well turned and thoroughly dried.

CAT-TAILS.

The cat-tail (*Typha latifolia*) finds conditions ideal for its growth in the rice fields. It is also present in canals, lateral supply ditches, shallow drainage ditches, and on poorly drained marshy land. The cat-tail is a perennial ranging in height from 3 to 9 feet. On the end of the stalk is a cylindrical flower head, which is 4 to 8 inches long and produces thousands of small seeds that are readily spread by wind and water.

Cat-tails can be pulled, but if they are thick the expense of pulling is prohibitive. Improved drainage and good cultivation each year, deep plowing, and exposure of the roots to the air until thoroughly dried help to control cat-tails. Cat-tails do not spread rapidly in fields that are well cultivated each year, but with poor cultivation they spread very fast, and are now a serious pest in the California rice fields. Good stands of rice aid in keeping cat-tails from entering the rice checks.

SEDGES OR UMBRELLA PLANTS.

The sedges, or umbrella plants (Cyperus), are present over the entire rice area. The perennial umbrella plants are usually found on the levees, ditch banks, and on poorly drained land. On poorly prepared seed beds, however, they are often present in the rice fields. On well-prepared land the perennial umbrella plants are seldom seen in the rice checks, while the smaller annual umbrella plants are found almost entirely there. Where stands are thin, this annual form is usually very thick, but where stands are good the rice appears to hold the umbrella plants in check. The annual umbrella plants have not been considered serious pests, although if very thick they no doubt interfere with the growth of the rice. Good seed-bed preparation and good stands of rice help to control umbrella plants. The seed is small and easily separated from rice during threshing.

CANARY GRASS.

Canary grass (*Phalaris paradoxa*), locally known as California timothy, is not a serious weed pest on well-prepared rice land. Canary grass begins growth during the late winter and early spring months. If not killed in preparing the seed bed, it interferes, if very thick, with the early growth of the rice crop, but the plants soon die after the land is submerged. Canary grass is easily controlled by good cultivation previous to sowing the rice.

CRABGRASS.

Crabgrass (*Syntherisma sanguinalis*) is found largely on the field levees, though occasionally it occurs out in the rice checks on the higher land, where the water is shallow. Crabgrass has an extensive root system and a spreading habit of growth, new roots developing from the nodes of the stems. This grass has not been troublesome in the California rice fields and can apparently be controlled by good cultivation.

JOINT-GRASS.

Joint-grass (*Paspalum distichum*) is found in shallow ditches and on rather swampy land. It has creeping stems and roots similar to Bermuda grass. It is not found very often in the rice checks. Good cultivation and dry fallow should eradicate it.

RED RICE.

Red rice (*Oryza rufipogon*) is the most common rice pest in all parts of the world. Red rice is present in the California rice fields, but does not appear to spread as it has in the other rice-producing countries. No red rice should be allowed to mature, however. Hand pulling is the best means of eradicating red rice.

In general, red-rice plants resemble ordinary or white-rice plants. The leaves of red rice are longer, broader, and lighter green than those

of Wataribune rice. The upper part of the leaves of red rice has a tendency to become yellowish when the plants are about 18 inches high. The red rice plants stool at an angle rather than upright, as in Wataribune, the head is more spreading, and the spikelets farther apart. Red rice shatters badly when mature. The grain resembles white rice, but when the husk is removed has a reddish seed coat which is objectionable to millers and consumers. The present infestations should be eradicated before the pest becomes well established.

Italian red rice is spreading in the California rice fields. This red variety is not the same as the one described above.

RED-STEM.

Red-stem (*Ammannia coccinea*) is present in the rice fields to some extent. It grows in shallow ditches, in the rice fields, and in swampy places. It competes with the rice and in this way reduces yields. The plants have reddish stems at maturity. The red flowers are borne at the base of the leaves, and the seeds are contained in a capsule about the size of a small pea. These capsules are often present in threshed rice. Good cultivation should help in the control of this weed.

CHEAT.

Cheat (*Bromus secalinus*) grows on the California wheat lands. If rice is sown on poorly prepared wheat land there is danger of having considerable cheat in the threshed rice crop. The rice mills have trouble in separating the cheat from the rice and therefore can not pay as much for rice which contains cheat. It is not safe, therefore, to sow rice in wheat land without first killing the weeds and volunteer grain, because volunteer wheat, barley, and cheat are all objectionable in rice.

OTHER CROPS FOR RICE LAND.

On the limited land available at the Biggs Rice Field Station attempts have been made to find some crop that could be grown in rotation with rice. Beans, corn, grain sorghums, cotton, and hemp have been tested for this purpose.

BEANS.

Beans have not been grown successfully at Biggs. It is difficult to obtain good stands, and the soil is so heavy that cultivation after irrigation is almost impossible. Insects are very troublesome during the early growth of the beans and in 1918 destroyed the crop before much growth had taken place. The soil at the station seems to be too heavy for successful bean culture.

CORN.

Corn has been grown at the Biggs Rice Field Station, but the results have not been satisfactory. Good stands have been obtained and the corn grew well and had a good color for about six weeks, but the plants then turned yellow and ceased growing. The unhealthy yellow color of the corn was undoubtedly due to poor drainage and the resulting high water table. The writer has observed that on the levees and high ground the growth of corn was more nearly normal and the plants retained a good healthy color. It is impossible to grow corn successfully on a heavy, poorly drained soil where the water table is

near the surface. On isolated fields with better drainage and on the lighter soil types good corn crops are grown, but at the station the results have not been satisfactory.

GRAIN SORGHUMS.

Several varieties of grain sorghum have been tested at the Biggs Rice Field Station. These include Dwarf Yellow milo, Standard Yellow milo, Dawn kafir, Sunrise kafir, Dwarf broom corn, Acme broom corn, and feterita. Good stands have been obtained with the sorghums each year, but the yields obtained have not been encouraging. The high water table checked growth, resulting in poor yields. On isolated fields with no submerged rice near, better growth and yields have been observed. Of the varieties tested, Dwarf Yellow milo was best.

COTTON.

In cooperation with the Office of Crop Acclimatization and Adaptation Investigations of the Bureau of Plant Industry several varieties of cotton have been grown at the Biggs Rice Field Station. In 1918 five varieties, Meade, Pima, Durango, Acala, and Lone Star, were included in the experiment. Good stands of each variety were obtained. Early in the season the cotton was irrigated about once every 18 days. The land was cultivated after each irrigation and often enough to retain a good mulch on the surface of the soil. The growth, while slow, was healthy in appearance until August, when it was noted that the plants had stopped growing and were turning yellow. Water was not applied after this condition was observed, but the plants failed to recover their normal appearance. The varieties began to flower on August 14. Growth was short, the plants had a sickly pale-yellow color, and very few bolls formed, opened, or matured. Pima was the most promising variety.

In 1919 the cotton varieties were planted on land that was fallowed in 1918, replowed shallow in the spring of 1919, and worked down into a good seed bed. Before planting, an attempt was made to list the ground, the land being ridged with an ordinary walking plow by backfurrowing. The cotton varieties were planted by hand on the ridges and were furrow-irrigated to germinate the seed. Good stands were obtained, though it was necessary to lift the soil crust from many of the young seedlings before they were able to emerge. The cotton made a fair growth during the early part of the season, but soon after the rice on adjoining fields was submerged and presumably the water table came nearer the surface, growth ceased, and the cotton turned yellow.

The Pima variety was grown near a levee where drainage was better. It attained a height of about 36 inches, few bolls formed, and very few matured. The Meade variety grew to a height of about 30 inches and formed many bolls, but very few opened. Durango did not form many bolls, and of these very few opened. Acala formed many bolls and nearly all of them opened; the average height of the plants was about 22 inches. Lone Star was about 20 inches in height, developed many bolls, and most of the bolls opened well. Lone Star and Acala were the most promising varieties. Three rows, 264 feet long, planted to Lone Star, the most promising variety, yielded 6½, 5½, and 5 pounds per row, respectively. Figured on an acre basis, this would be about 350 pounds of seed cotton per acre.

The cotton trials during 1918 and 1919 were disappointing in yield, but gave considerable information on the possibilities of cotton for use in rotation with rice.

The yellowing of the cotton plants both years was undoubtedly due to the high water table. This resulted in a stunted growth, weakened plants, and low yields. The writer has observed much better cotton on the same soil type where drainage was better and there were no adjoining rice fields.

HEMP.

In 1920 a small fallow plat was planted to hemp. The stand obtained was thin, and growth was very irregular during the season. In September some of the plants were 7 feet high, while adjoining plants were 8 to 12 inches high. The writer is unable to account for this remarkable variation in growth. It was observed during the summer that many of the young plants died. Some of these were examined and the taproot just below the surface of the ground found to be much enlarged, resembling flax canker. These plants may have been diseased.

SUMMARY OF EXPERIMENTS WITH OTHER CROPS.

Beans, corn, grain sorghums, and cotton at the Biggs Rice Field Station have not given satisfactory yields. The most evident reason for the poor growth of these crops is a high water table when grown adjoining submerged rice land. Wheat or barley appear to be the best crops to rotate with rice; in other words, the crops that were known to be adapted to the land before rice growing began should be grown. After growing rice, the land should be fallowed one summer before it is sown to wheat or barley.

SUMMARY.

Half a century ago attempts were made to grow rice in California but they were not successful. The rice industry in that State first assumed commercial importance in 1912, when 1,400 acres were sown in the Sacramento Valley, near Biggs.

In 1912 the Biggs Rice Field Station was established. The station is located 4½ miles northwest of Biggs.

The elevation of the station is 98 feet. The soil is Stockton clay adobe, typical of a large area on which rice is grown in the Sacramento Valley.

The summer months are hot and the winter months cool with occasional freezes. The months of June, July, and August are usually hot, with maximum temperatures ranging from 99° to 112° F. A daily range in temperature of 40 degrees is not uncommon during the growing season.

The average annual precipitation at the Biggs Rice Field Station from 1913 to 1921 was 21.67 inches. December, January, and February are the three months of greatest precipitation.

In general, this section has but little wind, though strong winds sometimes blow from the north or from the south.

The average evaporation from April to October for the years 1914, 1915, and 1921, was 42.794 inches. The average evaporation

for June, July, and August for the 9-year period, 1913 to 1921, was 25.696 inches.

In the depth-of-seeding experiments the highest average yield, 4,423 pounds of rice per acre, was obtained from the 2-inch depth. Shallow seeding is better than deep seeding.

The highest average yields when rice was drilled or broadcasted were obtained from the heaviest rates of seeding, the 100-pound rate in the first period and the 150-pound rate in the second period.

Drilling gave much better results than broadcasting in the first period, but the 150-pound rate during the second period produced about the same yield from both methods of seeding.

Rate-of-seeding experiments conducted during 1921 with three varieties of rice indicate that 150 pounds per acre is probably the best rate on old rice land.

In the date-of-seeding experiments there has been a marked decrease in yield with each successive date. Early seeding should be more generally practiced.

In a comparison of rough and smooth seed beds, there was a small increase in the average yield for the smooth seed bed.

The average yield by continuous cropping to rice for the 7-year period, 1913 to 1919, was 3,528 pounds per acre.

In the time-of-submergence experiments, the highest average yield, 3,699 pounds of rice per acre, was obtained by submerging 30 days after the rice emerged.

In the depth-of-submergence experiments, the highest average yield, 3,925 pounds per acre, was obtained by submerging the land 6 inches deep during the submergence period.

Slowly changing water gave a higher average yield than stagnant water. Fluctuation in the depth of submergence gave a higher average yield than slowly changing or stagnant water.

Land kept moist but not submerged during the usual submergence period produced dwarfed plants, small heads, and low yields of poor quality.

The best irrigation practice consists of irrigating the rice as often as necessary until 30 days after emergence; then submerging the land 6 inches deep continuously until the crop is ready to drain for harvest.

The fertilizer experiments conducted during the 3-year period, 1914 to 1916, inclusive, show that manure increased the average yield 879 pounds, sulphate of ammonia 651 pounds, dried blood 646 pounds, and cottonseed meal 583 pounds per acre.

After deducting the cost, the average increase in yield from the use of manure was worth $12.70; sulphate of ammonia, $9.09; dried blood, $8.16; and cottonseed meal, $5.85 per acre.

The fertilizer experiments indicate that nonnitrogenous fertilizers are unprofitable on Stockton clay adobe soil, while all nitrogenous fertilizers except nitrate of soda produced increased yields which were profitable.

Combinations of nitrogenous and nonnitrogenous fertilizers did not increase the yields as much as when the nitrogenous fertilizers alone were applied, and the increased cost of such combinations usually resulted in no profit and often a loss.

Manure is too scarce and difficult to apply for commercial use, but sulphate of ammonia, dried blood, or cottonseed meal can be cheaply applied, and the results indicate that either of these substances may be used profitably on commercial rice fields in California.

The varieties of rice most commonly grown in the United States are roughly classed as long grain, medium grain, and short grain. About 98 per cent of the rice grown in California consists of short-grain varieties.

The varieties of rice which belong in each class can be grouped according to maturity, as early, midseason, and late.

During the 9-year period 1913 to 1921, inclusive, many varieties and selections of rice have been grown in the nursery and plats at the Biggs Rice Field Station.

The varietal experiments indicate that the long-grain and medium-grain varieties are not well adapted, while the short-grain rices are well suited to California conditions.

Thirty-five varieties and strains of rice have been grown in tenth-acre plats and 9-year average yields obtained for seven varieties. The variety giving the highest average yield in the nine years was Wataribune, C. I. No. 1561, a late-maturing short-grain rice, yielding 4,364 pounds per acre. The Butte, C. I. No. 1564, a midseason short-grain variety, produced an average yield for the same period of 3,456 pounds per acre. Honduras, C. I. No. 1643, a long-grain late-maturing variety, produced an average yield for the same period of 2,600 pounds per acre.

During the 4-year period 1918 to 1921, the highest yielding variety or selection in the short-grain early group was Sue Hero, with an average yield of 1,843 pounds; in the midseason group, Selection No. 1561–3, 3,920 pounds; and in the late group, Selections Nos. 114 and 115, 2,995 pounds per acre. For the same period Early Prolific, a medium-grain midseason variety, produced an average yield of 2,337 pounds, and Selection No. 113, a long-grain midseason variety, 2,612 pounds per acre.

Early rice varieties mature in from 135 to 154 days from the date of the first irrigation, midseason varieties in about 161 days, and late varieties in 176 to 180 days.

Several hundred varieties and selections have been grown in the station nursery during the past eight years. Those varieties or selections which yield well in the rod-row nursery usually yield well in plats and larger fields.

The leading commercial rice varieties in California are Early Wataribune, Colusa (C. I. No. 1600), Onsen, Caloro, and Late Wataribune.

Barnyard grass (*Echinochloa crusgalli* and varieties) is the worst weed in the California rice fields. The methods of control consist of hand pulling, cultivation during fallow years, and continuous submergence from date of seeding until the rice crop is ready to drain.

Other weeds which are troublesome at times are scale-grass, spike rush, cat-tails, umbrella plants, and canary grasses.

Beans, corn, grain sorghums, cotton, and hemp have not been grown successfully, due to a high water table during the growing months. Wheat and barley appear to be the best crops to rotate with rice.

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